

Appendix B

Part 1

Economics of Alternatives



**U.S. Army Corps of Engineers
Memphis District**

Appendix B **ECONOMICS OF ALTERNATIVES**

INTRODUCTION

The purpose of this section is to present information pertaining to the annual benefits, costs, and economic justification of the alternatives that have been developed to address the flooding problems faced by the East Prairie, Missouri area. Alternatives presented in this section include a no action plan, the alternative recommended in the March 1997 St. Johns Bayou and New Madrid Floodway Missouri First Phase Limited Reevaluation Report (LRR), and four more environmentally sensitive versions of this plan.

GENERAL

For the purpose of this section, construction is assumed to begin in fiscal year 2012 and to be completed in fiscal year 2017. The period of analysis is from the end of 2018 through the end of 2067. For discounting purposes, costs are assumed to take place at the end of the year during which they are expended and benefits related to the physical construction from such costs are assumed to accrue one year after construction is completed. All benefits and costs accruing prior to the end of 2017 were compounded forward, and those occurring after the end of 2017 were discounted backward to determine the present value of project benefits and costs as of the end of 2017. The sum of the present values for each category was amortized over the period of analysis (50 years) to obtain average annual uniform equivalent values. The First Phase feature of Alternative 2 was chosen to illustrate the methodology used to calculate annual economic benefits and costs in this appendix. These features are chosen for illustration purposes only and may or may not be recommended for construction.

The price levels and the land use used in this section are based on 2012 conditions. Estimates of land use are based on information obtained from area farmers, the University of Missouri Office of Social and Economic Data Analysis, and the USDA Census of Agriculture. The area is predominately rural and dependent on agriculture for its livelihood. Little urban development occurs in the area.

Two interest rates are used for plan formulation purposes in this section. The Mississippi River Levees feature consisting of a 1,500 foot levee closure and gravity structure at the south end of the New Madrid Floodway was formulated using a previously authorized interest rate of 2.5%. This interest rate was used because the levee closure was authorized for construction as part of the Flood Control Act of 1954. The levee closure is an integral part of the ongoing MRT project which has been ongoing since the great flood of 1927. The remaining features were formulated using the current interest rate for Federal water resource projects of 4%. However, for sensitivity purposes, all features of the project are presented using an array of interest rates; 2.5%, 4.0%, and 7.0%.

ALTERNATIVES

A total of six alternatives are presented in this section. A brief description of each alternative is presented in the following paragraphs. A more detailed description of the alternatives can be found in the main body of this report.

Alternative 1. Alternative 1 is the "No Action" alternative. This is the same as existing conditions and forms the basis by which the other alternatives are measured.

Alternative 2. Alternative 2 is part of the total project authorized by the Water Resources Development Act of 1986. Alternative 2 is presented in three sub-sections, Alternatives 2.1, 2.2, and 2.3. Alternative 2.1 is the St Johns Basin only alternative. Alternative 2.2 is the New Madrid Floodway portion including the MRL feature. Alternative 2.3 is both basins combined. The MRL feature consists of a 1,500 -foot levee closure and gravity structure at the south end of the New Madrid Floodway, which will prevent backwater flooding from the Mississippi River. The remainder of Alternative 2 consists of two pumping stations, a 1,500 cfs station in the New Madrid Floodway basin and a 1,000 cfs station in the St Johns Bayou basin. Also included is channel enlargement on St Johns Bayou, Birds Point Levee Ditch, and St James Ditch. The channel work is designed to provide an outlet for the city of East Prairie, Missouri. All of the channel work occurs within the St Johns Bayou basin. No channel improvement occurs within the New Madrid Floodway basin.

Alternative 3.1. Alternative 3.1 is a refinement to allow seasonal flooding during the winter and early spring for migratory waterfowl and to allow fish access through the gates into the New Madrid Floodway. This will be accomplished by modifying the start-stop pump/gate closure elevations. Other environmental features include establishing a riparian corridor along the improved channels.

Alternative 3.2. Alternative 3.2 is very similar to 3.1 but uses a lower start-stop pump/gate closure elevation. This alternative will provide more flood protection but will also require additional mitigation as compared to Alternative 3.1.

Alternative 4.1. Alternative 4.1 is a further refinement which allows river connectivity to the New Madrid Floodway up to an elevation of 290 feet. It is intended to allow more seasonal flooding which will reduce anticipated benefits while saving additional costs for mitigation features.

Alternative 4.2. Alternative 4.2 is very similar to 4.1 but uses a land reforestation on all agricultural areas below 2.90. This alternative should provide significant flood protection by taking cropland and putting it in a non-damaging use (forests). It should also require significantly less mitigation lands but will come with a significantly higher implementation price.

METHODOLOGY USED TO ESTIMATE ANNUAL DAMAGES AND BENEFITS

The benefits consist of agricultural benefits and streets and roads. The agricultural benefits are composed of inundation reduction (flood damage reduction) and intensification.

AGRICULTURAL BENEFITS.

The agricultural benefits are classified into two categories: inundation reduction (flood damage reduction) and intensification. Inundation reduction benefits consist of damage reduction to development under present and projected future changes under without project conditions. Intensification benefits result from additional income that would be obtained as a result of changes in development caused by the project.

a. Land Use. The area is characterized primarily by agricultural operations. Woodlands are virtually nonexistent. The only areas of woods are scattered and very small. The remaining trees are on spoil banks or channel side slopes of drainage channels or in other low-lying areas. The soils are generally poorly drained and fertile. Because of their favorable properties for agricultural use, these soils have significantly influenced development in the area. There is little urban development occurring in the first phase's project area. The town of East Prairie, Missouri is located in the benefited area. There is also scattered rural development in the form of farm residences and associated buildings, etc. throughout the area. The closest large population center is Sikeston, Missouri, which lies immediately north of the project area.

Future without- and with-project land use is expected to remain essentially the same as current conditions. There are no large tracts of woodlands remaining in the area that are expected be cleared. In fact there is a trend toward reforestation being driven by the Wetland Reserve Program which pays farmers to plant frequently flooded croplands to trees. Whether or not this trend continues will be dependent on the relative profitability of farming. Current conditions show that farming is very profitable which should slow or halt this trend. However, due to the past tree plantings, a small continuation of this trend was forecast for this analysis.

b. Crop Data. The crop prices used in this section are the FY 2012 Current Normalized Prices developed by the Economic Research Service (ERS). The ERS is one of four agencies in the Research, Education, and Economics Mission Area of the U.S. Department of Agriculture (USDA). The ERS provides economic analysis on efficiency, efficacy, and equity issues related to agriculture, food, the environment, and rural development to improve public and private decision making. Normalized Prices have been used by Federal agencies in water and related land resources planning, since implementation of the Water Resources Planning Act of 1965 which required their use. The ERS annually calculates Normalized Prices for evaluating alternative development and management plans for water and related land resources. Normalized Prices smooth out the effects of short-term price fluctuations so that plans

can be evaluated on a more realistic basis rather than using current prices, which may be lower or higher than normal because of short-lived phenomena. The ERS estimates these prices based on 5-year moving averages of actual market prices.

Flooding plays an important role in a farmer's decision making process. As the risk of flooding increases, a farmer is less likely to plant higher value crops and use high management production techniques. The project area can be divided into flood zones where these significant changes in cropping practices occur. Dividing the agricultural sector into flood zones helps to better evaluate impacts on the agricultural sector. The crop yields used in this analysis are also affected by flood risk and reflected by the differences between the flood zones. The yields in the lower zone are considered flood risk constrained while those in the upper zone are considered non-flood risk constrained crop management practices. Flood risk constrained management is a condition where flood risk/uncertainty causes inefficient crop management practices. However, with non-flood risk constrained management, there are no inefficiencies. This section used the 5 year flood zone as the point where significant changes in farming practices occur in both the St Johns Bayou and the New Madrid Floodway Basins. The area above the 5 year frequency is where more intensive and profitable crops are grown while slightly lower value crops are grown below the 5 year flood zone.

(1). MRL Feature Data. The primary crops grown in the New Madrid Floodway, absent the MRL Feature, are soybeans, corn, grain sorghum, and wheat. Soybeans is the primary cash crop in the lower portion that is subject to frequent backwater flooding. Table B-1 presents 2012 land use and crop data used to assess the effects of the MRL feature of Alternatives 2, 3, and 4. Land use for future (2067) conditions was also estimated. The calculation of future crop budgets was accomplished by projecting both crop yields per acre and levels of crop production inputs per acre. The price levels for both crops and production costs were held constant at 2012 price levels. The methodology used to project crop yields and levels of production inputs is consistent with that used for other Memphis District flood control studies. A first degree polynomial function was fit to crop budget input and output indices published by the Economic Research Service of the U.S. Department of Agriculture. The resulting regression equations were $y=0.0167348X-32.4349327$ for crop yields and $y=0.0051037X-9.1882495$ for production inputs. The correlation coefficients were 0.94873 and 0.37086 respectively. The output equation was a very good fit as reflected by the correlation coefficient and tested statistically significant at the 1 percent level of significance. The input equation was not as good a fit and only tested significant at the 2 percent level. Projected crop data is presented in Table B-2.

(2). Remaining Features Data. Current (2012) crop data for the remaining features of Alternatives 2 and 3 is presented in Table B-3. This data reflects current cropping practices within the St Johns Bayou basin, which is already protected from backwater flooding from the Mississippi River. However, it reflects a significant shift in cropping patterns for the New Madrid Floodway basin. The shift is primarily away from soybeans to more profitable and higher value crops such as corn and double cropping soybeans and wheat. It also reflects a shift to increased use of irrigation in the New Madrid Floodway as farmers increased investments are protected from the frequent backwater flooding.

Table B-1
New Madrid Floodway Agricultural Land Use
Existing Conditions (2011)
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Item	Corn		Rice	Dryland Cotton			Irrigated Cotton			Soybeans		Wheat	Double Crop Soybeans		Grain Sorghum		Total
	Dryland	Irrigated		Lint	Seed	Total	Lint	Seed	Total	Dryland	Irrigated		Dryland	Irrigated	Dryland	Irrigated	
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)	(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)		
0.5 Year Floodplain																	
Price	3.38									8.29	8.29	4.22	8.29	8.29	5.64		
Yield	120.0									34.0	42.5	55.0	29.8	38.3	42.50		
Gross Value	405.60									281.86	352.33	232.10	246.63	317.09	239.70		
Production Cost	368.97									227.23	273.60	214.31	213.37	261.54	223.07		
Net Return	36.63									54.63	78.74	17.79	33.26	55.55	16.63		
Distribution	0.053									0.399	0.416	0.130	0.063	0.067	0.002		1.130
Wt Net Return	1.94									21.80	32.75	2.31	2.10	3.72	0.03		64.66
5 Year-SPF Floodplain																	
Price	3.38	3.38	10.81	0.530	161.60		0.530	161.60		8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	140.0	180.0	72.00	935	0.823		1,100	0.968		40.0	50.0	70.0	35.0	45.0	50.00	62.00	
Gross Value	473.20	608.40	778.32	495.55	132.96	628.51	583.00	156.43	739.43	331.60	414.50	295.40	290.15	373.05	282.00	312.48	
Production Cost	375.37	384.97	503.05			595.40			606.34	228.42	274.87	216.01	214.22	262.56	225.50	250.50	
Net Return	97.83	223.43	275.27			33.11			133.09	103.18	139.63	79.39	75.93	110.49	56.50	61.98	
Distribution	0.096	0.100	0.037			0.050			0.048	0.250	0.260	0.147	0.072	0.075	0.006	0.006	1.147
Wt Net Return	9.39	22.34	10.18			1.66			6.39	25.80	36.30	11.67	5.47	8.29	0.34	0.37	138.20

Table B-2
New Madrid Floodway Basin Agricultural Land Use
Future Without Project Conditions (2067)
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Item	Corn		Rice	Dryland Cotton			Irrigated Cotton			Soybeans		Wheat	Double Crop Soybeans		Grain Sorghum		Total
	Dryland	Irrigated		Seed	Lint	Total	Seed	Lint	Total	Dryland	Irrigated		Dryland	Irrigated	Dryland	Irrigated	
	(bu)	(bu)	(cwt)	(lb)	(ton)	(lb)	(ton)	(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)	(cwt)		
0-5 Year Floodplain																	
Price	3.38									8.29	8.29	4.22	8.29	8.29	5.64		
Yield	195.0									50.0	62.0	84.0	43.0	56.0	66.0		
Gross Value	659.10									414.50	513.98	354.48	356.47	464.24	372.24		
Production Cost	430.55									265.15	319.26	250.08	248.98	305.19	260.30		
Net Return	228.55									149.35	194.72	104.40	107.49	159.05	111.94		
Distribution	0.053									0.399	0.416	0.130	0.063	0.067	0.002	1.130	
Wt Net Return	12.11									59.59	81.01	13.57	6.77	10.66	0.22	183.93	
5 Year-SPF Floodplain																	
Price	3.38	3.38	10.81	0.53	161.60		0.53	161.60	0.00	8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	227.0	292.0	107.0	1364.0	1,200		1605.0	1,412		58.0	73.0	107.0	51.0	66.0	78.0	97.0	
Gross Value	767.26	986.96	1156.67	722.92	193.97	916.89	850.65	228.24	1078.89	480.82	605.17	451.54	422.79	547.14	439.92	488.88	
Production Cost	438.02	449.22	587.01			694.77			707.53	266.54	320.74	252.06	249.97	306.38	263.13	292.31	
Net Return	329.24	537.74	569.66			222.12			371.36	214.28	284.43	199.48	172.82	240.76	176.79	196.57	
Distribution	0.096	0.100	0.037			0.050			0.048	0.250	0.260	0.147	0.072	0.075	0.006	0.006	
Wt Net Return	31.61	53.77	21.08			11.11			17.83	53.57	73.95	29.32	12.44	18.06	1.06	1.18	

Table B-3
St Johns Bayou and New Madrid Floodway Basins Agricultural Land Use
With the MRL Features
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Item	Corn		Rice	Dryland Cotton			Irrigated Cotton			Soybeans		Wheat	Double Crop Soybeans		Grain Sorghum		Total
	Dryland	Irrigated		(bu)	(bu)	(cwt)	(lb)	Seed	Total	(lb)	Seed	Total	(bu)	(bu)	(bu)	(bu)	(cwt)
0-5 Year Floodplain																	
Price	3.38	3.38	10.81	0.53	161.60		0.53	161.60		8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	140.0	180.0	72.0	935.0	0.823		1100.0	0.968		40.0	50.0	70.0	35.0	45.0	50.0	62.0	
Gross Value	473.20	608.40	778.32	495.55	132.96	628.51	583.00	156.43	739.43	331.60	414.50	295.40	290.15	373.05	282.00	312.48	
Production Cost	375.37	384.97	503.05			595.40			606.34	228.42	274.87	216.01	214.22	262.56	225.50	250.50	
Net Return	97.83	223.43	275.27			33.11			133.09	103.18	139.63	79.39	75.93	110.49	56.50	61.98	
Percent Distribution	0.096	0.100	0.037			0.050			0.048	0.250	0.260	0.147	0.072	0.075	0.006	0.006	1.147
Weighted Net Return	9.39	22.34	10.18			1.66			6.39	25.80	36.30	11.67	5.47	8.29	0.34	0.37	138.20
5 Year-SPF Floodplain																	
Price	3.38	3.38	10.81	0.53	161.60		0.53	161.60		8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	155.0	200.0	80.0	1040.0	0.915		1225.0	1.078		45.0	55.0	78.0	39.0	50.0	55.0	69.0	
Gross Value	523.90	676.00	864.80	551.20	147.90	699.10	649.25	174.20	823.45	373.05	455.95	329.16	323.31	414.50	310.20	347.76	
Production Cost	380.17	391.37	506.81			595.40			606.34	229.27	275.72	217.37	214.90	263.41	226.35	251.69	
Net Return	143.73	284.63	357.99			103.70			217.11	143.78	180.23	111.79	108.41	151.09	83.85	96.07	
Percent Distribution	0.171	0.114	0.021			0.066			0.046	0.182	0.118	0.124	0.073	0.051	0.084	0.054	
Weighted Net Return	24.58	32.45	7.52			6.84			9.99	26.17	21.27	13.86	7.91	7.71	7.04	5.19	170.52

Projected (2067) land use is presented in Table B-4. The procedure to project this data is the same as for the MRL feature in the previous paragraph.

c. Agricultural Flood Damage Prevented. Flood damage reduction benefits to crops are based on the difference between average annual equivalent flood damages for without- and with-project conditions. Flood damages are calculated by applying crop damage rates per flooded acre to expected annual acre estimates. This procedure for Alternative 3.1 is described in the following paragraphs.

(1). Expected Annual Acres. The number of expected annual cleared acres flooded was calculated by the use of partial duration frequency curves and stage-area information. Results indicate that there are approximately 21,632 expected annual cleared acres flooded by headwater in the project area under existing conditions. The project lowers this figure to 1,271 acres for a reduction of 20,361 or a 94% reduction (Table B-5). Backwater floods in the New Madrid Floodway inundate approximately 69,700 cleared acres under existing conditions. With the MRL closure in place this figure is reduced 82% to 15,657 acres. Of the remaining 15,657 acres in the New Madrid Floodway, the pumping station will reduce an additional 6,131 acres. In the St Johns Basin Headwater flooding is reduced 46% by the pump station from 26,669 acres to 14,409 acres.

Headwater and backwater flooding can and do occur concurrently. To avoid duplication of benefits, the overlapping effect had to be eliminated. From historical hydrologic data, it was determined that when headwater and backwater floods occurred concurrently, the backwater influence was dominant. Therefore, only adjustment of headwater damages was necessary to avoid duplication in the estimation of total damage. Also, from this historical hydrologic data, an estimate was made of the proportion of time that headwater and backwater flooding occurred concurrently. Using this data, factors were developed to reduce the headwater benefits. These factors are presented in Table B-6. These factors represent the percent of the time that backwater flooding would not overlap the effects of the proposed channel work. For instance, for St Johns Bayou, Reach 1, the channel improvements would provide headwater benefits approximately 66.3 percent of the time. The remaining 33.7 percent, backwater would be the dominant factor with backwater filling the channels and inundating adjacent cropland.

(2). Crop Damage Rates. Agricultural crop damage rates were calculated using a computer program entitled Crop Flood Damage Analysis or CFDA. It was developed by Mississippi State University for the Lower Mississippi Valley Division, Corps of Engineers. This program calculates crop flood damages by analysis of daily flood events. The program also has the capability to calculate damage from multiple flooding events in the same area during the same year. In addition, the program allows for specific crop replanting and/or crop substitution. The program is structured to compute flood damages based on the time of the flood event in relation to the sequence of agricultural operations that have occurred in the production process. Duration factors, expressed as the number of days required to cause damage, are developed for four stages of plant development. Normal, late planting, and last day of planting dates are also developed by crop. These dates are extremely important as they, in conjunction

Table B-4
St Johns Bayou and New Madrid Floodway Basins Agricultural Land Use Projected to 2067
With the MRL Features
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Item	Corn		Rice	Dryland Cotton			Irrigated Cotton			Soybeans		Wheat	Double Crop Soybeans		Grain Sorghum		Total	
	Dryland	Irrigated			Lint	Seed	Total	Seed	Lint	Total	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated		
	(bu)	(bu)	(cwt)	(lb)	(ton)		(lb)	(ton)		(bu)	(bu)	(bu)	(bu)	(bu)	(cwt)	(cwt)		
0-5 Year Floodplain																		
Price	3.38	3.38		10.81	0.53	161.60		0.53	161.60		8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	227.0	292.0		107.0	1364.0	1.200		1605.0	1.412		58.0	73.0	107.0	51.0	66.0	78.0	97.0	
Gross Value	767.26	986.96		1156.67	722.92	193.97	916.89	850.65	228.24	1078.89	480.82	605.17	451.54	422.79	547.14	439.92	488.88	
Production Cost	438.02	449.22		587.01			694.77			707.53	266.54	320.74	252.06	249.97	306.38	263.13	292.31	
Net Return	329.24	537.74		569.66			222.12			371.36	214.28	284.43	199.48	172.82	240.76	176.79	196.57	
Percent Distribution	0.096	0.100		0.037			0.050	0.000	0.000	0.048	0.250	0.260	0.147	0.072	0.075	0.006	0.006	
Weighted Net Return	31.61	53.77		21.08			11.11			17.83	53.57	73.95	29.32	12.44	18.06	1.06	1.18	324.97
5 Year-SPF Floodplain																		
Price	3.38	3.38		10.81	0.53	161.60		0.53	161.60		8.29	8.29	4.22	8.29	8.29	5.64	5.04	
Yield	251.0	324.0		119.0	1518.0	1.336		1788.0	1.573		66.0	80.0	120.0	57.0	73.0	86.0	108.0	
Gross Value	848.38	1095.12		1286.39	804.54	215.87	1020.41	947.64	254.27	1201.91	547.14	663.20	506.40	472.53	605.17	485.04	544.32	
Production Cost	443.62	456.69		591.39			694.77			707.53	267.53	321.74	253.65	250.77	307.37	264.13	293.70	
Net Return	404.76	638.43		695.00			325.64			494.37	279.61	341.46	252.75	221.76	297.80	220.91	250.62	
Percent Distribution	0.171	0.114		0.021			0.066			0.046	0.182	0.118	0.124	0.073	0.051	0.084	0.054	
Weighted Net Return	69.21	72.78		14.59			21.49			22.74	50.89	40.29	31.34	16.19	15.19	18.56	13.53	386.81

Table B-5
Expected Annual Acres
Alternative 3.1, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS

Item	Without-Project		Alternative 3.1		Reduction	
	0-5 Year	5 Yr-SPF	0-5 Year	5 Yr-SPF	0-5 Year	5 Yr-SPF
Headwater						
St Johns Bayou	5,418	52	818	0	4,600	52
St James Ditch	7,538	168	246	0	7,292	168
Birds Point Levee Ditch	8,392	64	207	0	8,185	64
Backwater						
St Johns Basin						
Present	12,504	1,714	7,417	264	5,087	1,450
Future 1/	10,792	1,659	6,472	256	4,320	1,403
New Madrid Floodway Basin						
MRL Closure						
Present	68,382	1,318	15,657	0	52,725	1,318
Future 1/	66,612	1,318	14,408	0	52,204	1,318
Pump						
Present	14,291	1,366	9,510	16	4,781	1,350
Future 1/	13,052	1,356	8,404	16	4,648	1,340

1/ Future reflects conversion of cropland to WRP.

Table B-6
Backwater-Headwater Overlap Factors
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS

Item	Backwater-Headwater Overlap Factors
St Johns Bayou, Reach 1	0.663
St James Ditch	0.973
BPLD Reach 1	0.854

with the duration factors, are the base dates from which flood damages, crop replanting, crop substitution, and crop yield reductions are developed. Three cost vectors were developed for the crop budgets used in the program to assess flood damages. These include: (a) production costs and fixed harvesting equipment costs; (b) expected net returns to lands, management, and general farm overhead; and (c) operation revenues consisting of realized gross value of the harvested crop. Major data requirements include crop distribution, net and gross returns by crop, crop substitution data, daily flood duration data, and cleared acres flooded on a daily basis. Current crop mixes, production costs, crop yields, and crop prices were incorporated into the CFDA runs to yield the current crop damage rates per acre presented in Table B-7.

(3). Annual Benefit. The expected annual acres calculated in (1) are multiplied by the average damage per cleared acre flooded from (2) above to obtain crop damage estimates for with- and without-project conditions. These damage estimates are then adjusted by the appropriate backwater-headwater overlap factors presented in Table B-6. The results are presented in Table B-8 for various years. These damages and benefits are put on an annual basis using standard discounting procedures as outlined in the introduction. Total annual benefits for Alternative 3.1 (less the MRL feature) are estimated at \$3,336,000 at the current (4.0 percent) discount rate. Including the MRL feature adds an additional \$2,598,000 to the project's benefits for a total of \$5,934,000.

(4) Risk Analysis. This section provides an estimate of the risk inherent with the economic and hydrologic data used to evaluate the flood damage prevented benefits. It addresses the areas where risk and uncertainty are known to exist so that the economic performance of the project can be expressed in terms of probability distributions. Risk-based analyses incorporate risk and uncertainty into the calculation of agricultural damages by using a simulation technique in which multiple iterations select from the full range of possible values for selected key variables utilized in the computation of proposed project benefits. The resulting mean (average) value and probability distributions provide the decision maker with a more complete analogy of possible results.

This analysis was performed using an Excel spreadsheet in conjunction with an add-on simulation model entitled @Risk. The @Risk program uses Monte Carlo simulation to derive the possible occurrences. Monte Carlo simulation utilizes randomly generated numbers to simulate the occurrences of selected variables from established ranges and distributions. It incorporates the range (maximum and minimum) of possible values for an input variable in the flood damage calculation, and specifies the statistical distribution of likely outcomes over the chosen range. In the case where a normal distribution is assumed, 68 percent of the occurrences of a particular outcome would fall within (plus or minus) one standard deviation, on either side of the mean, and 95 percent within two standard deviations on either side of the mean. With each sample or iteration, a value is selected and utilized through the computational process to derive the proposed project benefits. The sum of all sampled values divided by the number of samples (iterations) yields the expected mean value. This routine is accomplished simultaneously for each of the variables evaluated for its inherent uncertainty.

Table B-7
Crop Damage Rates
Alternative 3.1, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Item	Without-Project		Alternative 3.1	
	0-5 Year	5 Yr-SPF	0-5 Year	5 Yr-SPF
Headwater				
Present Conditions	64.34	25.45	64.34	25.45
Future Conditions	112.65	53.37	112.65	53.37
Backwater				
St Johns Basin				
Present Conditions	64.34	25.45	37.86	20.71
Future Conditions	112.65	53.37	65.98	40.60
New Madrid Floodway Basin				
MRL Closure				
Present Conditions	38.49	9.25	45.29	0.00
Future Conditions	69.57	18.04	80.88	0.00
Pump				
Present Conditions	72.40	28.90	14.68	28.90
Future Conditions	125.14	61.50	23.68	61.50

Table B-8
Agricultural Crop Damages and Benefits
Alternative 3.1, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Year	MRL Closure			First Phase Features		
	Without-Project	Alternative 3.1	Benefit	Without-Project	Alternative 3.1	Benefit
2017	2,860,000	2,860,000	0	3,532,000	3,532,000	0
2018	2,896,000	766,000	2,130,000	3,570,000	542,000	3,028,000
2027	3,220,000	839,000	2,381,000	3,914,000	586,000	3,328,000
2037	3,579,000	921,000	2,658,000	4,296,000	635,000	3,661,000
2047	3,939,000	1,002,000	2,937,000	4,677,000	683,000	3,994,000
2057	4,298,000	1,084,000	3,214,000	5,059,000	732,000	4,327,000
2067	4,658,000	1,165,000	3,493,000	5,441,000	781,000	4,660,000
Average Annual Equivalent						
Includes Backwater-						
Headwater Overlap	3,501,000	903,000	2,598,000	4,212,000	625,000	3,587,000
Excludes Overlap						3,336,000

The initial step in constructing an @Risk simulation is to identify the sources of uncertainty. Some sources of risk and uncertainty arise from measurement errors, small sample sizes, estimation and forecasting errors, and modeling errors. The variables chosen and the amounts they are allowed to vary during the simulation are presented in Table B-9. All distribution functions are assumed to be normal distributions. The variables chosen were Stage Frequency (1.5 foot standard deviation), Stage Area (10%), Projection Factors (25%), Crop Yields (10%), Crop Prices (15%), Production Costs (5%), and Interest Rate (0.25%).

The @Risk simulation was performed utilizing 3,000 iterations, or different combinations, of the chosen variables. The 68 and 95 percent confidence bands around the mean results are plus/minus one and two standard deviations, respectively. An additional step was taken to identify which variable(s) contributed the most to uncertainty. The simulation was run again for all variables, varying each individually while holding the remaining variables constant. The most important variable was the 1.5-foot variation in stage frequency followed by the 10 percent variation in the stage area relationship. The results of the individual simulations for Alternative 3.1 and their ranking are presented in Table B-9. One standard deviation yields a range from a low of \$4,688,000 in agricultural flood protection benefits to a high of \$7,204,000.

AGRICULTURAL NONCROP BENEFITS.

Flood damages also occur to noncrop items (i.e., farm property other than crops). These include damages to farm supplies; farm roads; drainage ditches, including V and W types; fences; irrigation systems; and landforming and leveling. Agricultural noncrop damages are based on a study, "Agricultural Non-Crop Flood Damage: Mississippi Delta, Mississippi" (September 1994), conducted by the Mississippi State University Department of Agricultural Economics at the Mississippi Agricultural and Forestry Experiment Station. These values in this study were updated to 2012 price levels to reflect current production and equipment costs.

The MSU report estimated flood damages for three types of flood events in 11 counties (limited, moderate, and severe) in the lower Yazoo and Mississippi River delta areas in the Vicksburg District. The limited category was used in this analysis because it was felt to be a conservative estimate. Many farming practices in the study are directly comparable to practices in lower Yazoo River delta area. But due to the geographical distance between the areas it was felt prudent to err to the conservative side. Updated noncrop damage rates ranged upward to a high of \$57.65 per acre with an average of \$24.69 for 2012 conditions. Future projections were made using the crop input factor described previously yielding a 2067 per acre rate of \$28.80. These rates were applied to the expected annual acres flooded presented previously in Table B-5 for without- and with-project conditions. They were discounted using the current discount rate of 4.0%. The results of this analysis for Alternative 3.1 is presented in Table B-10 for individual project features. The MRL Closure provides \$1,422,000 in benefits while the remainder of Alternative 3.1 provides \$785,000 in benefits for a total of \$2,207,000.

Table B-9
Agricultural Flood Damage Prevented
Results of Risk Analysis, Variables Ranked by Importance
Alternative 2, First Phase Features
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Item	Variation	Agricultural Flood Damage Prevented		Rank
		Mean Value	Standard Deviation	
All Variables		5,946,000	1,258,000	
Stage Frequency	1.5 Feet	5,948,000	1,202,000	1
Stage Area	10 Percent	5,921,000	298,000	2
Projection Factors	25 Percent	5,921,000	184,000	3
Crop Yields	10 Percent	5,921,000	152,000	4
Crop Prices	15 Percent	5,922,000	142,000	5
Production Costs	5 Percent	5,921,000	83,000	6
Interest Rate	3.75% to 4.25%	5,922,000	2,000	7

Table B-10
Agricultural Non-Crop Damages and Benefits
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Year	MRL Closure			First Phase Features		
	Without-Project	Alternative 3.1	Benefit	Without-Project	Alternative 3.1	Benefit
2017	1,746,000	1,746,000	0	1,586,000	1,586,000	0
2018	1,750,000	390,000	1,360,000	1,589,000	458,000	1,131,000
2027	1,788,000	395,000	1,393,000	1,612,000	461,000	1,151,000
2037	1,830,000	400,000	1,430,000	1,638,000	464,000	1,174,000
2047	1,872,000	405,000	1,467,000	1,665,000	467,000	1,198,000
2057	1,914,000	410,000	1,504,000	1,691,000	470,000	1,221,000
2067	1,956,000	415,000	1,541,000	1,717,000	473,000	1,244,000
Average Annual Equivalent						
Includes Backwater-Headwater Overlap	1,821,000	399,000	1,422,000	1,326,000	463,000	863,000
Excludes Overlap						785,000

AGRICULTURAL INTENSIFICATION BENEFITS.

Flood protection, full or partial, reduces the financial risks involved in farming operations. Such a reduction allows an intensification of farmlands, which results in higher yields and, subsequently greater net returns to land. Intensification benefits result from an intensification of land that is presently being farmed as no conversion from non-farmed lands is expected to take place. These benefits result from a change to a more profitable crop distribution combination and from more intensive farm inputs that provide greater yields on the individual crops. Flood control improvements would permit better use of land protected from frequent flooding.

a. Increased Net Returns per Acre. The intensification benefits are based on the increase in net returns between with- and without-project conditions and are adjusted to account for the increased residual damage to the intensified practices caused by any remaining flooding. The increase in net productive value per cleared acre after installation of the plan was derived from the data presented in Tables B-3 and B-4. These practices are based on those used by the area farmers under without-project conditions in the above 5-year flood zone less the below 5-year zone.

b. Acres Intensified. These values were applied to the number of acres to be intensified yielding the basic benefit values. The acres intensified are the cleared acres flooded by the 5-year without-project flood less the cleared acres flooded by the 5-year with-project flood (Table B-11).

c. Annual Benefit. The basic benefit values are adjusted downward to account for any increased damage caused by planting higher value crops on those acres flooded after project installation (Table B-12) and the backwater-headwater overlap factors presented in Table B-6 and discussed previously. The results are presented in Table B-13 for various years. These benefits are put on an annual basis using standard discounting procedures as outlined in the introduction. Total annual benefits are estimated at \$2,697,000 for the MRL Closure and \$917,000 for the remaining features at the current (4.0 percent) discount rate.

Risk Analysis. This section provides an estimate of the risk inherent with the economic and hydrologic data used to evaluate the agricultural intensification benefits. It addresses the areas where risk and uncertainty are known to exist so that the economic performance of the project can be expressed in terms of probability distributions. This analysis was performed very similar to the method used in the Agricultural Benefit section. It uses an Excel spreadsheet in conjunction with a simulation model entitled @Risk. It incorporates the range (maximum and minimum) of possible values for an input variable and specifies the statistical distribution of likely outcomes over the chosen range. In the case where a normal distribution is assumed, 68 percent of the occurrences of a particular outcome would fall within (plus or minus) one standard deviation, on either side of the mean, and 95 percent within two standard deviations on either side of the mean. The variables chosen and the amounts they were allowed to vary are presented in Table B-14. All distribution functions are assumed to be normal. The variables chosen were Stage Frequency (1.5 foot standard deviation), Crop Prices (15%), Crop

Table B-11
Area Subject to Intensification
Five-Year Flood Zone
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS

Item	Without-Project	Alternative 3.1	Area Intensified
Headwater			
St Johns Bayou	3,248	1,074	2,174
St James Ditch	7,284	330	6,954
Birds Point Levee Ditch	5,932	0	5,932
Backwater			
St Johns Basin			
Present	14,527	11,286	3,241
Future 1/	12,912	9,895	3,017
New Madrid Floodway Basin			
MRL Closure			
Present	61,518	18,034	43,484
Future 1/	60,664	17,370	43,294
Pump			
Present	18,034	10,219	7,815
Future 1/	17,370	9,590	7,780

1/ Future reflects conversion of cropland to WRP.

Table B-12
Increased Residual Damage due to Intensified Practices
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
October 2012 Price Levels

Stream/Reach	2012 Increased Residual Damage	2067 Increased Residual Damage
Headwater		
St Johns Bayou	6,793	12,897
St James Ditch	2,914	5,533
Birds Point Levee Ditch	2,581	4,900
Backwater		
St Johns Basin	20,531	36,286
New Madrid Basin		
MRL Closure	729,726	1,450,501
Pump	3,648	6,865

Table B-13
Agricultural Intensification Benefits
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Year	MRL Closure	First Phase Features
2017	0	0
2018	2,134,000	773,000
2027	2,435,000	850,000
2037	2,770,000	935,000
2047	3,105,000	1,021,000
2057	3,440,000	1,106,000
2067	3,775,000	1,191,000
Average Annual Equivalent	2,697,000	917,000

Table B-14
Agricultural Intensification Benefits
Results of Risk Analysis, Variables Ranked by Importance
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Item	Variation	Agricultural Flood Damage Prevented		Rank
		Mean Value	Standard Deviation	
All Variables		3,455,000	618,000	
Stage Frequency	1.5 Feet	3,457,000	416,000	1
Crop Prices	15 Percent	3,560,000	380,000	2
Crop Yields	10 Percent	3,560,000	191,000	3
Stage Area	10 Percent	3,560,000	178,000	4
Projection Factors	25 Percent	3,560,000	169,000	5
Production Costs	5 Percent	3,560,000	77,000	6
Interest Rate	3.75% to 4.25%	3,560,000	60,000	7

Yields (10%), Stage Area (10%), Projection Factors (25%), Production Costs (5%), and Interest Rate (0.25%).

The @Risk simulation was performed utilizing 3,000 iterations, or different combinations, of the chosen variables. The 68 and 95 percent confidence bands around the mean results are plus/minus one and two standard deviations, respectively. The simulation was run again, varying each variable individually while holding the remaining variables constant. The most important variable was the 1.5-foot variation in stage frequency followed by the 15 percent variation in crop prices. The results of the individual simulations and their ranking are presented in Table B-14. One standard deviation yields a range from a low of \$2,837,000 in agricultural flood protection benefits to a high of \$4,073,000.

STREET AND ROAD BENEFITS.

On several occasions in recent years the Missouri Highway Department has had to sandbag a section of Interstate 55 to prevent overtopping of the highway by floodwaters that back up St Johns Ditch. Representatives of the Department have considered raising this section of the Interstate in the past. They have not done so yet because of the potential of construction of this project. Construction of the pumping station on St Johns Bayou will relieve this flooding problem and save the State of Missouri considerable highway funds. The reduced cost of reconstructing Interstate 55 is estimated at \$83,101,000 (Table B-15). This estimate was prepared by the Cost Section of the Memphis District COE. When annualized at the current discount rate and a 50 year period of analysis, an annual benefit of \$3,439,000 directly attributable to the St Johns pumping station is estimated.

Other less significant benefits from area roads are also presented in Table B-15. The reduction of headwater flooding in the St Johns Basin is estimated at \$102,000 annually while backwater benefits accrue to the New Madrid Floodway pump station (\$36,000). The MRL Closure provides \$169,000 in annual benefits at 4.0%.

METHODOLOGY USED TO ESTIMATE PROJECT ANNUAL COSTS

The project costs, like the annual benefits, are based on current price levels (October 2012), estimated over a 50-year period of analysis plus the installation period, and discounted to the end of the project installation period using the current Federal discount rate (4.0%). Economic costs associated with the project are initial investment charges, operation and maintenance charges, and replacement charges.

Table B-15
Annual Street and Road Benefit
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Item	\$
St Johns Pump Station	
Cost of Raising I55	83,101,000
Present Value Factor	0.88900
Present Value	73,877,000
Amortization Factor	0.04655
Annual Benefit	3,439,000
Benefit to Other Public Roads from Prior Reports	
Headwater	102,000
Backwater	
New Madrid Basin	
MRL Closure	169,000
Pump	36,000
Total	3,746,000

PROJECT FIRST COSTS.

Project financial costs total \$164,779,000 for Alternative 3.1 which includes the MRL Features. These costs are based on October 2012 price levels. Included in these costs is the cost of mitigation reforestation. Mitigation reforestation totals \$40,358,000. However, a portion of this cost is viewed as a financial cost and not an economic cost. The mitigation reforestation is converting lands from cropland to woodlands. The total cost of the cropland is included in the financial costs because the sponsor will have to expend this amount to acquire the lands. However, the woodlands will still have significant remaining value. Therefore, only the difference between the cropland and woodland costs is viewed as an economic cost to be included in the project's benefit-to-cost ratio. The project economic costs are only \$16,915,000 which is a \$23,443,000 difference. Project economic costs total \$141,337,000 and are assumed to be end of year expenditures for discounting purposes.

ANNUAL INTEREST AND SINKING FUND COSTS.

The annual interest and sinking fund costs are summarized in Table B-16. They are based on a reference point at the beginning of year 2018 (end of year 2017), the current discount rate of 4.0 percent, and a 50 year period of analysis. Annual interest charges are \$5,994,000 and annual sinking fund charges are \$980,000. Total annual interest and sinking fund costs are \$6,974,000.

ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS.

a. Channel Items. The estimated costs of channel maintenance and replacements for the First Phase feature of Alternative 3.1 are presented in Table B-17. These expenditures reflect previous experience with similar projects from this region. Brush-kill is required at 4 year intervals. Channel maintenance is required at 20 year intervals. Bridge replacements are required every 30 to 50 years as dictated by the life of the new bridges. Total maintenance and replacement cost is approximately \$37,000.

b. Pumping Stations. Operation, maintenance, and replacement costs associated with the pumping stations are estimated at \$109,000 annually for the New Madrid Pump and \$129,000 for the St Johns Pump (Table B-18). They include electricity and labor costs replacement of pump impellers every 40 years, gear reducers every 30 years, electric motor stators and motor control centers every 35 years, and roof replacement at 20 year intervals.

Table B-16
Annual Investment Cost
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Year	St Johns Basin			New Madrid Floodway Basin			Total	Present Value Factor	St Johns Basin			New Madrid Floodway Basin			Total
	Channels	Pump	Subtotal	MRL Closure	NNF Pump	Subtotal			Channels	Pump	Subtotal	MRL Closure	NNF Pump	Subtotal	
2012	549,000	313,000	862,000			862,000	1.21665	667,941	380,811	1,048,752	0	0	0	1,048,752	
2013	3,219,000	1,835,000	5,054,000		317,000	317,000	5,371,000	1.16986	3,765,779	2,146,693	5,912,472	0	370,846	370,846	6,283,318
2014	3,258,000	1,858,000	5,116,000		2,096,000	2,096,000	7,212,000	1.12486	3,664,794	2,089,990	5,754,784	0	2,357,707	2,357,707	8,112,491
2015	12,970,000	7,395,000	20,365,000	19,476,000	13,057,000	32,533,000	52,898,000	1.08160	14,028,352	7,998,432	22,026,784	21,065,242	14,122,451	35,187,693	57,214,477
2016	12,970,000	7,395,000	20,365,000	24,459,000	9,860,000	34,319,000	54,684,000	1.04000	13,488,800	7,690,800	21,179,600	25,437,360	10,254,400	35,691,760	56,871,360
2017	1,731,000	987,000	2,718,000	14,852,000	2,740,000	17,592,000	20,310,000	1.00000	1,731,000	987,000	2,718,000	14,852,000	2,740,000	17,592,000	20,310,000
Total	34,697,000	19,783,000	54,480,000	58,787,000	28,070,000	86,857,000	141,337,000		37,346,666	21,293,726	58,640,392	61,354,602	29,845,404	91,200,006	149,840,398
Annual Interest								0.04000	1,494,000	852,000	2,346,000	2,454,000	1,194,000	3,648,000	5,994,000
Annual Sinking Fund								0.00655	244,000	139,000	383,000	402,000	195,000	597,000	980,000
Total Interest and Sinking Fund								0.04655	1,738,000	991,000	2,729,000	2,856,000	1,389,000	4,245,000	6,974,000

Table B-17
Annual Operation, Maintenance, and Replacement Costs for Channel Items
Alternative3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Item	Cost			Annual Cost				Total
	Brushkill	Cleanout	Replacements	Brushkill	Cleanout	Replacements		
St John's Bayou								
Miles	4.50	4.50						
\$			371,000	460,000	1,207	861	10,555	13,000
Frequency	4 Years	20 Years	30 Years	50 Years				
St James Ditch								
Miles	10.80	10.80						
\$			816,000	210,000	2,609	1,911	14,151	19,000
Frequency	4 Years	20 Years	30 Years	50 Years				
Birds Point Levee Ditch								
Miles	12.40	12.40						
\$					3,197	2,282		5,000
Frequency	4 Years	20 Years						

Table B-18
Annual Operation, Maintenance, and Replacement Costs for Pump Stations
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels, 4.0%)

Item	New Madrid Station			St Johns Station		
	Interval	Replacement Cost	Annual Cost	Interval	Replacement Cost	Annual Cost
Replacement Cost and Interval						
Pump Impellers	40	325,000	3,277	40	277,000	2,686
Gear Reducer	30	210,000	2,576	30	119,000	1,708
Electric Motor Stators	35	136,000	2,030	35	121,000	1,427
Motor Control Center	35	381,000	4,674	35	277,000	3,268
Roof	20	47,000	1,512	20	37,000	1,145
Maintenance Cost						
Roof	7	36,000	4,709	7	26,000	3,270
Estimated Maintenance	1	21,000	21,000	1	21,000	21,000
Operating Cost						
Labor			26,000			26,000
Energy Charges			38,000			63,000
Facility Charge			5,000			5,000
Total Annual Costs			109,000			129,000

SUMMARY OF PLANS

ALTERNATIVE 2.1.

Alternative 2.1 is the St Johns Bayou portion of the total project. It includes the St Johns Bayou pumping station and the channel work on St Johns Bayou, St James Ditch, and Birds Point Levee Ditch which is designed to provide an outlet to the city of East Prairie, Missouri.

a. Annual Benefit. Total annual benefits for Alternative 2.1 are presented in Table B-19. Agricultural benefits account for 49 percent of the feature's benefits. Inundation reduction benefits comprise 91 percent of the benefits followed by intensification at 9 percent.

b. Annual Cost. Annual costs Alternative 2.1 are also presented in Table B-19. Annual interest and sinking fund costs reflecting the financing costs of the project account for 94 percent of the alternative's cost. The remaining 6 percent is operation and maintenance that is primarily operation and maintenance of the pumping station and associated facilities.

c. Summary. Alternative 2.1 has a healthy benefit-to-cost ratio of 2.4 to 1. All increments of the alternative are economically justified.

ALTERNATIVE 2.2.

Alternative 2.2 is the New Madrid Floodway portion of the total project. It includes the 1,500 foot levee closure and structure at the south end of the New Madrid Floodway which will prevent backwater flooding from the Mississippi River and the New Madrid pumping station. Benefits and costs for the closure (MRL feature) are presented for both 4.0% and 2.5% discount rates.

a. Annual Benefit. Total annual benefits for Alternative 2.2 are presented in Table B-19. Agricultural benefits account for 97 percent of the feature's benefits. Inundation reduction benefits comprise 64 percent of the benefits with intensification accounting for 36 percent.

b. Annual Cost. Annual costs Alternative 2.2 are also presented in Table 19. Annual interest and sinking fund costs reflecting the financing costs of the project account for 98 percent of the alternative's cost. The remaining 2 percent is operation and maintenance that is primarily operation and maintenance of the pumping station and associated facilities.

c. Summary. Alternative 2.2 also has a healthy benefit-to-cost ratio of 1.5 to 1. All increments of this alternative are also economically justified.

Table B-19
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 2
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	Alternative 2.1 St Johns Basin			Alternative 2.2 New Madrid Basin				Alternative 2.3 Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total		
Discount Rate	4.000%	4.000%	4.000%	4.000%	4.000%	2.500%	4.000%	4.000%
Benefits								
AG FDP	1,464,000	691,000	2,155,000	1,038,000	2,779,000	2,858,000	3,817,000	5,972,000
AG NonCrop	461,000	163,000	624,000	232,000	1,502,000	1,512,000	1,734,000	2,358,000
AG Intensification	486,000	105,000	591,000	512,000	2,825,000	2,919,000	3,337,000	3,928,000
Streets and Roads	102,000	3,439,000	3,541,000	106,000	211,000	214,000	317,000	3,858,000
Total	2,513,000	4,398,000	6,911,000	1,888,000	7,317,000	7,503,000	9,205,000	16,116,000
Costs								
Interest	1,494,000	852,000	2,346,000	1,383,000	3,758,000	2,312,000	5,141,000	7,487,000
Sinking Fund	244,000	139,000	383,000	227,000	615,000	948,000	842,000	1,225,000
O&M	37,000	129,000	166,000	137,000	0	0	137,000	303,000
Total	1,775,000	1,120,000	2,895,000	1,747,000	4,373,000	3,260,000	6,120,000	9,015,000
Excess Benefits	738,000	3,278,000	4,016,000	141,000	2,944,000	4,243,000	3,085,000	7,101,000
BCR	1.4	3.9	2.4	1.08	1.7	2.3	1.5	1.8

ALTERNATIVE 2.3.

Alternative 2.3 is the combined or total. It includes all features of both basins including the 1,500 foot levee closure and structure at the south end of the New Madrid Floodway. Total annual benefits for this alternative are \$16,116,000. Total annual costs are \$9,015,000. This alternative has a benefit-to-cost ratio of 1.8 to 1. A summary of Alternative 2.3 is also presented in Table B-19.

ALTERNATIVE 3.1.

Alternative 3.1 is a refinement of Alternative 2 above, which incorporates measures designed to avoid some of the detrimental environmental effects associated with Alternative 2. Included is a different start-stop pump/gate closure scenario which will allow for additional winter waterfowl flooding and spring fish passage. Annual benefits and annual costs for the Alternative 3.1 are presented in Table B-20. Like Alternative 2, the majority of benefits are agricultural and inundation reduction. The annual costs reflect a decrease in mitigation costs due to higher start-stop pump/gate closure elevations. All increments are economically feasible as shown in Table B-20. This alternative has also been designated as the NED plan.

ALTERNATIVE 3.2.

Alternative 3.2 is a further refinement of Alternative 3.1, which incorporates a slightly start-stop pump/gate closure scenario which will allow for less winter waterfowl flooding and spring fish passage. However, it still allows for less impact than Alternative 2 and therefore has lower mitigation costs. Annual benefits and annual costs for the Alternative 3.2 are presented in Table B-21. The majority of benefits are also agricultural and inundation reduction. The annual costs while reflecting a decrease in mitigation costs are higher than Alternative 3.1. All increments are economically feasible as shown in Table B-21.

ALTERNATIVE 4.1.

Alternative 4.1 is a further refinement that allows Mississippi River connectivity in the New Madrid Floodway until an elevation of 290 is reached. At this time the MRL gates are closed. This alternative provides for even more winter waterfowl flooding and spring fish passage. However, because of the increased flooding it provides for less flood protection but has less environmental impacts and therefore lower mitigation costs. Annual benefits and annual costs for the Alternative 4.1 are presented in Table B-22. The majority of benefits are also agricultural and inundation reduction. All increments are economically feasible as shown in Table B-22.

Table B-20
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	St Johns Basin			New Madrid Basin				Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total		
Discount Rate	4.000%	4.000%	4.000%	4.000%	4.000%	2.500%	4.000%	4.000%
Benefits								
AG FDP	1,464,000	691,000	2,155,000	1,181,000	2,598,000	2,672,000	3,779,000	5,934,000
AG NonCrop	461,000	163,000	624,000	161,000	1,422,000	1,432,000	1,583,000	2,207,000
AG Intensification	486,000	105,000	591,000	326,000	2,697,000	2,787,000	3,023,000	3,614,000
Streets and Roads	102,000	3,439,000	3,541,000	36,000	169,000	171,000	205,000	3,746,000
Total	2,513,000	4,398,000	6,911,000	1,704,000	6,886,000	7,062,000	8,590,000	15,501,000
Costs								
Interest	1,494,000	852,000	2,346,000	1,194,000	2,454,000	1,510,000	3,648,000	5,994,000
Sinking Fund	244,000	139,000	383,000	195,000	402,000	619,000	597,000	980,000
O&M	37,000	129,000	166,000	109,000	0	0	109,000	275,000
Total	1,775,000	1,120,000	2,895,000	1,498,000	2,856,000	2,129,000	4,354,000	7,249,000
Excess Benefits	738,000	3,278,000	4,016,000	206,000	4,030,000	4,933,000	4,236,000	8,252,000
BCR	1.4	3.9	2.4	1.1	2.4	3.3	2.0	2.1

Table B-21
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 3.2
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	St Johns Basin			New Madrid Basin				Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total		
Discount Rate	4.000%	4.000%	4.000%	4.000%	4.000%	2.500%	4.000%	4.000%
Benefits								
AG FDP	1,464,000	691,000	2,155,000	1,233,000	2,622,000	2,697,000	3,855,000	6,010,000
AG NonCrop	461,000	163,000	624,000	191,000	1,433,000	1,443,000	1,624,000	2,248,000
AG Intensification	486,000	105,000	591,000	378,000	2,697,000	2,787,000	3,075,000	3,666,000
Streets and Roads	102,000	3,439,000	3,541,000	49,000	174,000	176,000	223,000	3,764,000
Total	2,513,000	4,398,000	6,911,000	1,851,000	6,926,000	7,103,000	8,777,000	15,688,000
Costs								
Interest	1,494,000	852,000	2,346,000	1,246,000	2,666,000	1,640,000	3,912,000	6,258,000
Sinking Fund	244,000	139,000	383,000	204,000	437,000	673,000	641,000	1,024,000
O&M	37,000	129,000	166,000	115,000	0	0	115,000	281,000
Total	1,775,000	1,120,000	2,895,000	1,565,000	3,103,000	2,313,000	4,668,000	7,563,000
Excess Benefits	738,000	3,278,000	4,016,000	286,000	3,823,000	4,790,000	4,109,000	8,125,000
BCR	1.4	3.9	2.4	1.2	2.2	3.1	1.9	2.1

Table B-22
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 4.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	St Johns Basin			New Madrid Basin				Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total		
Discount Rate	4.000%	4.000%	4.000%	4.000%	4.000%	2.500%	4.000%	4.000%
Benefits								
AG FDP	1,464,000	691,000	2,155,000	1,357,000	2,501,000	2,572,000	3,858,000	6,013,000
AG NonCrop	461,000	163,000	624,000	70,000	1,380,000	1,389,000	1,450,000	2,074,000
AG Intensification	486,000	105,000	591,000	157,000	2,564,000	2,649,000	2,721,000	3,312,000
Streets and Roads	102,000	3,439,000	3,541,000	7,000	153,000	156,000	160,000	3,701,000
Total	2,513,000	4,398,000	6,911,000	1,591,000	6,598,000	6,766,000	8,189,000	15,100,000
Costs								
Interest	1,494,000	852,000	2,346,000	1,142,000	2,203,000	1,355,000	3,345,000	5,691,000
Sinking Fund	244,000	139,000	383,000	188,000	360,000	556,000	548,000	931,000
O&M	37,000	129,000	166,000	84,000	0	0	84,000	250,000
Total	1,775,000	1,120,000	2,895,000	1,414,000	2,563,000	1,911,000	3,977,000	6,872,000
Excess Benefits	738,000	3,278,000	4,016,000	177,000	4,035,000	4,855,000	4,212,000	8,228,000
BCR	1.4	3.9	2.4	1.1	2.6	3.5	2.1	2.2

ALTERNATIVE 4.2.

Alternative 4.2 is similar in nature to Alternative 4.1. In addition to the features of 4.1 it includes the reforestation of all croplands below 290. This will prevent the flood damages on these lands by converting them to a non-damaging land use. Annual benefits and annual costs for Alternative 4.2 are presented in Table B-23. The majority of benefits are also agricultural and inundation reduction. The annual costs while reflecting a decrease in mitigation costs are higher than Alternative 3.1. All increments are economically feasible except for the New Madrid Floodway Pumping Station. In addition to the traditional benefits presented in this analysis, Alternative 4.2 has the potential for providing significant nutrient capture and carbon sequestration benefits due to reforesting the croplands below 290. While these benefits cannot be included in the NED analysis, they could potentially be significant. These potential benefits will be addressed later in the Sensitivity Analysis section.

NED PLAN.

A true NED plan was not identified in that all components of the plans were not optimized or sized. For example, no additional pumping station sizes were analyzed. Instead the authorized components were analyzed with differing mitigation scenarios with the focus on lowering environmental impacts while not having significant impacts on the project's outputs. The resulting plan that maximized excess benefits was chosen as the NED plan. This plan is Alternative 3.1 with benefits over costs of \$8,252,000. Alternative 4.1 is next with excess benefits of \$8,228,000 followed by Alternative 3.2 with \$8,125,000, and Alternative 2 with of \$7,101,000.

SENSITIVITY ANALYSIS

DISCOUNT RATES.

The Independent Expert Peer Review identified the need to present a sensitivity analysis that included multiple interest rates. This need was primarily due to the project having two different interest rates for the two authorizations. The closure levee used an authorized interest rate of 2.5 percent while the remainder of the project uses the current rate which is not 4.0 percent. So to address this concern it was decided to present three interest rates that bracket the current rate. The rates chosen were 2.5 percent, 4.0 percent, and 7 percent. Table B-24 compares Alternative 3.1 at these three discount rates. As expected all increments of the project are feasible at 2.5 percent. It is also interesting to note that all increments except the New Madrid Floodway Pumping Station and the St Johns Basin Channels are viable at 7 percent.

NUTRIENT CAPTURE AND CARBON SEQUESTRATION BENEFITS. Alternative 4.2 targets all of the cropland below elevation 290 for purchase and reforestation. This is approximately 16,417 acres under existing conditions or 15,768 under future without-project conditions. The 649 acre

Table B-23
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 4.2
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	St Johns Basin			New Madrid Basin				Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total		
Discount Rate	4.000%	4.000%	4.000%	4.000%	4.000%	2.500%	4.000%	4.000%
Benefits								
AG FDP	1,464,000	691,000	2,155,000	217,000	3,321,000	3,412,000	3,538,000	5,693,000
AG NonCrop	461,000	163,000	624,000	57,000	1,742,000	1,753,000	1,799,000	2,423,000
AG Intensification	486,000	105,000	591,000	157,000	2,564,000	2,649,000	2,721,000	3,312,000
Streets and Roads	102,000	3,439,000	3,541,000	106,000	211,000	214,000	317,000	3,858,000
Total	2,513,000	4,398,000	6,911,000	537,000	7,838,000	8,028,000	8,375,000	15,286,000
Costs								
Interest	1,494,000	852,000	2,346,000	1,370,000	3,735,000	2,297,000	5,105,000	7,451,000
Sinking Fund	244,000	139,000	383,000	224,000	611,000	943,000	835,000	1,218,000
O&M	37,000	129,000	166,000	84,000	0	0	84,000	250,000
Total	1,775,000	1,120,000	2,895,000	1,678,000	4,346,000	3,240,000	6,024,000	8,919,000
Excess Benefits	738,000	3,278,000	4,016,000	-1,141,000	3,492,000	4,788,000	2,351,000	6,367,000
BCR	1.4	3.9	2.4	0.32	1.8	2.5	1.4	1.7

Table B-24
Annual Benefits, Costs, Excess Benefits, and Benefit-to-Cost Ratios
Alternative 3.1
St Johns Bayou and New Madrid Floodway, EIS
(October 2012 Price Levels)

Item	St Johns Basin			New Madrid Basin			Both Basins
	Headwater	Backwater	Total	Pump	Closure	Total	
Discount Rate	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
Benefits	2,633,000	3,698,000	6,331,000	1,744,000	7,062,000	8,806,000	15,137,000
Costs	1,323,000	861,000	2,184,000	1,141,000	2,129,000	3,270,000	5,454,000
Excess Benefits	1,310,000	2,837,000	4,147,000	603,000	4,933,000	5,536,000	9,683,000
BCR	2.0	4.3	2.9	1.5	3.3	2.7	2.8
Discount Rate	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Benefits	2,513,000	4,398,000	6,911,000	1,704,000	6,886,000	8,590,000	15,501,000
Costs	1,775,000	1,120,000	2,895,000	1,498,000	2,856,000	4,354,000	7,249,000
Excess Benefits	738,000	3,278,000	4,016,000	206,000	4,030,000	4,236,000	8,252,000
BCR	1.4	3.9	2.4	1.1	2.4	2.0	2.1
Discount Rate	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Benefits	2,326,000	5,683,000	8,009,000	1,640,000	6,603,000	8,243,000	16,252,000
Costs	2,886,000	1,738,000	4,624,000	2,386,000	4,588,000	6,974,000	11,598,000
Excess Benefits	-560,000	3,945,000	3,385,000	-746,000	2,015,000	1,269,000	4,654,000
BCR	0.8	3.3	1.7	0.7	1.4	1.2	1.4

difference is due to lands that are expected to convert to woodlands in the future under the Wetland Reserve Program. Elevation 290 is inundated approximately 1.5 times per year from Mississippi River backwater. The elevations below 290 are inundated more frequently. Because of this frequent flooding along with reforestation these lands have great potential to receive significant benefits from carbon sequestration.

A report prepared in 2000 by Leonard Shabman and Laura Zepp of the Department of Agricultural and Applied Economics at Virginia Tech presents information on the potential value of similar woodlands in the Yazoo River basin in Mississippi. The report was prepared in cooperation with the US Environmental Protection Agency. It is titled, "An Approach for Evaluating Nonstructural Actions with Application to the Yazoo River (Mississippi) Backwater Area. Table E-2 on page 127 of the report gives ranges from \$4.71 per acre to \$12.19 per acre depending on the species of tree established and the elevation of flooding. Table B-25 reproduces some of this data.

If the 16,417 acre area could be valued at even the low end of the figures in Table B-25, the area would still accrue a substantial benefit. The low end of these benefits would be approximately \$77,000 (16,417 acres times \$4.71) annually while the upper end would be \$200,000 (16,417 times \$12.19).

Table B-25
Annual Equivalent Value of per acre Carbon Returns on Alligator (hydric) Soils - Reach One

	Elevation				
	One	Two	Three	Four	Five thru Eight
Sycamore	\$6.18	\$9.62	\$9.99	\$9.99	\$9.99
Green Ash	\$6.54	\$10.44	\$10.86	\$10.86	\$10.87
Sweet Gum	\$6.18	\$9.62	\$9.99	\$9.99	\$9.99
Nuttal Oak	\$5.54	\$9.35	\$10.85	\$10.86	\$10.86
Seeded Nuttal Oak	\$4.71	\$7.94	\$9.22	\$9.23	\$9.23
Cottonwood	\$9.09	\$9.33	\$9.33	\$9.33	\$9.33
Cottonwood-Nuttal Oak Inerplanted	\$8.63	\$11.05	\$11.94	\$12.19	\$12.19
Cherrybark Oak	-	-	-	-	-
Bald Cypress	\$6.67	\$10.67	\$11.10	\$11.10	\$11.10

Source: "An Approach for Evaluating Nonstructural Actions with Application to the Yazoo River (Mississippi) Backwater Area,
by Leonard Shabman and Laura Zepp, Department of Agricultural and Applied Economics, Virginia Tech, February 7, 2000.

Appendix B

Part 2

Economic Cost Estimates



**U.S. Army Corps of Engineers
Memphis District**

Alt 2.1

St. Johns Bayou Cost Estimate - Authorized Project

Item Description	Amount
01 LANDS AND DAMAGES	
Item 1	\$0
Item 3, St. Johns Abyou (0.0 - 3.0)	\$931,000
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000
Item 5, St. Johns Bayou Pumping Sation	\$728,000
Item 6, St. James Ditch	\$1,310,000
waterfowl	\$2,835,000
TOTAL 01 Lands and Damages	\$6,793,000

02 RELOCATIONS

Item 4 St. Johns Bayou	\$928,000
Item 4, Setback Levee Ditch	\$74,000
Item 5, St. Johns Pumping Station	\$186,000
Item 6, St. James Ditch	\$2,009,000
TOTAL 02 Relocations	\$3,197,000

02 CHANNELS AND CANALS

Item 1	\$0
Item 3, St. Johns Bayou	\$1,945,000
Item 4, St. Johns and Setback Levee	\$2,118,000
Item 5, St. Johns Bayou Pumping Station	\$1,356,000
Item 6, St. James Ditch	\$947,000
TOTAL 09 Channels and Canals	\$6,366,000

13 Pumping Plants

Item 5, St. Johns Bayou Pumping Station	\$17,861,000
Seismic	\$1,786,100
TOTAL 13 Pumping Stations	\$19,647,100

30 PLANNING, ENGINEERING, and DESIGN

Phase 1 PED	\$980,000
VE Study (Items 3, 4, and 6)	\$150,000
VE Study (Items 2 and 5)	\$100,000
TOTAL PED	\$1,230,000

31 CONSTRUCTION MANAGEMENT

Phase 1, Supervision and Administration \$2,259,000
TOTAL S+A \$2,259,000

TOTAL PHASE 1 ST. JOHNS BAYOU \$39,492,100

Mitigation & Monitoring

Mitigation & Monitoring	
Shorebirds	\$1,587,677.50
Borrow Pits	\$72,562.50
Buffer	\$1,218,421.88
Reforestation	\$14,393,266.25
Total Mitigation	\$17,271,928.13

Adaptive Management and Monitoring \$1,178,000

TOTAL ALTERNATIVE 2.1 \$57,942,028.13

Alt. 2.2

Item Description	SJNM Feature	MRL Feature
01 Lands and Damages		
Levee Closure	\$48,000	
Setback Levee Grade Raise	\$630,000	
Acquisition	\$210,000	
waterfowl	\$2,628,000	
TOTAL 01 Lands and Damages		\$3,516,000
11 Levees and Floodwalls		
Item 2, Gravity Outlet and portion of Closure	\$12,093,000	
Item 2 New Madrid Floodway Closure	\$2,592,000	
Setback Levee Raise	\$8,121,720	
TOTAL Levees and Floodwalls		\$22,806,720
13 Pumping Plants		
Item 2, NMF Pumping Station	\$19,647,100	
Seismic	\$1,964,710	
TOTAL 13 Pumping Stations		\$21,611,810
30 PLANNING, ENGINEERING, and DESIGN		
NMF Pumping Staion PED	\$756,413.35	
Item 2 PED		\$513,975.00
Setback Levee Raise PED		\$284,260.20
VE Study	\$50,000	\$50,000
TOTAL PED		\$806,413.35
31 CONSTRUCTION MANAGEMENT		
NMF Pumping Station	\$1,188,650	
Item 2		\$807,675
Setback Levee Grade Raise		\$446,695
TOTAL S+A		\$1,254,370
TOTAL PHASE 1		\$23,606,873
Mitigation & Monitoring		
Shorebirds	\$10,370,126	
Borrow Pits	\$11,250	
Buffer	\$0	
Reforestation	\$40,773,979	
Batture Land Reforestation	\$28,131,760	
Big Oak Tree State Park Resoration	\$4,605,743	
Floodplain Lake	\$2,087,225	
subtotal	\$0	\$85,980,084
SJNM Adjustment (9%)	\$7,738,207.57	\$78,241,876.50
Mitigation & Monitoring Total		\$78,241,876.50
Adaptive Management and Monitoring		\$4,712,000
TOTAL ALTERNATIVE 2.2		\$32,523,080.47
		\$111,379,201

Item Description	SJNM Feature	MRL Feature	
01 LANDS AND DAMAGES			
Item 1	\$0		
Item 3, St. Johns Bayou (0.0 - 3.0)	\$931,000		
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000		
Item 5, St. Johns Bayou Pumping Station	\$728,000		
Item 6, St. James Ditch	\$1,310,000		
waterfowl	\$2,835,000		
TOTAL 01 Lands and Damages	\$6,793,000	\$3,516,000	
02 RELOCATIONS			
Item 4 St. Johns Bayou	\$928,000		
Item 4, Setback Levee Ditch	\$74,000		
Item 5, St. Johns Pumping Station	\$186,000		
Item 6, St. James Ditch	\$2,009,000		
TOTAL 02 Relocations	\$3,197,000		
02 CHANNELS AND CANALS			
Item 1	\$0		
Item 3, St. Johns Bayou	\$1,945,000		
Item 4, St. Johns and Setback Levee	\$2,118,000		
Item 5, St. Johns Bayou Pumping Station	\$1,356,000		
Item 6, St. James Ditch	\$947,000		
TOTAL 09 Channels and Canals	\$6,366,000		
13 Pumping Plants			
NMF Pumping Station	\$19,647,100		
NMF Seismic	\$1,964,710		
Item 5, St. Johns Bayou Pumping Station	\$17,861,000		
Seismic	\$1,786,100		
TOTAL 13 Pumping Stations	\$41,258,910		
30 PLANNING, ENGINEERING, and DESIGN			
NMF PED	\$756,413		
Phase 1 PED	\$980,000		
VE Study (Items 3, 4, and 6)	\$150,000		
VE Study (Items 2 and 5)	\$100,000		
TOTAL PED	\$1,986,413		
31 CONSTRUCTION MANAGEMENT			
NMF S+A	\$1,188,650		
Phase 1, Supervision and Administration	\$2,259,000		
TOTAL S+A	\$3,447,650		
TOTAL PHASE 1 ST. JOHNS BAYOU	\$63,048,973	TOTAL NMF Closure	\$28,425,324.80
Mitigation & Monitoring		Mitigation & Monitoring	
Shorebirds	\$1,587,677.50	Shorebirds	\$10,370,126
Borrow Pits	\$72,562.50	Borrow Pits	\$11,250
Buffer	\$1,218,421.88	Buffer	\$0
Reforestation	\$14,393,266.25	Reforestation	\$40,773,979
Batture Land Reforestation	\$0.00	Batture Land Reforestation	\$28,131,760
Big Oak Tree State Park Restoration	\$0.00	Big Oak Tree State Park Restoration	\$4,605,743
Floodplain Lake	\$0	Floodplain Lake	\$2,087,225
subtotal	17,271,928	subtotal	85,980,084
SJNM Adjustment (9%)	7,738,208	SJNM Adjustment (9%)	78,241,876
Mitigation & Monitoring Total	25,010,136	Mitigation & Monitoring Total	78,241,876
Adaptive Management and Monitoring	\$1,178,000	Adaptive Management and Monitoring	\$4,712,000
TOTAL ALTERNATIVE 2.3	\$89,237,108.59	TOTAL ALTERNATIVE 2.3	\$111,379,201.30

Item Description	SJNM Feature	MRL Feature
01 LANDS AND DAMAGES		
Item 1	\$0	
Item 3, St. Johns Bayou (0.0 - 3.0)	\$931,000	
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000	
Item 5, St. Johns Bayou Pumping Station	\$728,000	
Item 6, St. James Ditch	\$1,310,000	
waterfowl	\$2,835,000	
TOTAL 01 Lands and Damages	\$6,793,000	\$3,516,000
02 RELOCATIONS		
Item 4 St. Johns Bayou	\$928,000	
Item 4, Setback Levee Ditch	\$74,000	
Item 5, St. Johns Pumping Station	\$186,000	
Item 6, St. James Ditch	\$2,009,000	
TOTAL 02 Relocations	\$3,197,000	\$22,806,720
02 CHANNELS AND CANALS		
Item 1	\$0	
Item 3, St. Johns Bayou	\$1,945,000	
Item 4, St. Johns and Setback Levee	\$2,118,000	
Item 5, St. Johns Bayou Pumping Station	\$1,356,000	
Item 6, St. James Ditch	\$947,000	
TOTAL 09 Channels and Canals	\$6,366,000	\$848,235
13 Pumping Plants		
NMF Pumping Station	\$19,647,100	
NMF Seismic	\$1,964,710	
Item 5, St. Johns Bayou Pumping Station	\$17,861,000	
Seismic	\$1,786,100	
TOTAL 13 Pumping Stations	\$41,258,910	\$807,675
30 PLANNING, ENGINEERING, and DESIGN		
NMF PED	\$756,413	
Phase 1 PED	\$980,000	
VE Study (Items 3, 4, and 6)	\$150,000	
VE Study (Items 2 and 5)	\$100,000	
TOTAL PED	\$1,986,413	\$446,695
31 CONSTRUCTION MANAGEMENT		
NMF S+A	\$1,188,650	
Phase 1, Supervision and Adminstration	\$2,259,000	
TOTAL S+A	\$3,447,650	\$1,254,370
TOTAL PHASE 1 ST. JOHNS BAYOU	\$63,048,973	\$28,425,324.80
Mitigation & Monitoring		
Shorebirds	\$1,587,678	
Borrow Pits	\$72,563	
Buffer	\$1,218,422	
Reforestation	\$14,393,266	
Batture Land Reforestation	\$0	
Big Oak Tree State Park Resoration	\$0	
Floodplain Lake	\$0	
subtotal	\$17,271,928	
SJNM Adjustment (9%)	\$4,512,854	
Mitigation & Monitoring Total	\$21,784,782	\$45,629,972
Adaptive Management and Monitoring	\$1,178,000	\$4,712,000
TOTAL ALTERNATIVE 3.1	\$86,011,755.39	\$78,767,296.69

Item Description	SJNM Feature	MRL Feature
01 LANDS AND DAMAGES		
Item 1	\$0	
Item 3, St. Johns Bayou (0.0 - 3.0)	\$931,000	Levee Closure \$48,000
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000	Setback Levee Grade Raise \$630,000
Item 5, St. Johns Bayou Pumping Station	\$728,000	Acquisition \$210,000
Item 6, St. James Ditch	\$1,310,000	waterfowl \$2,628,000
waterfowl	\$2,835,000	
TOTAL 01 Lands and Damages	\$6,793,000	TOTAL 01 Lands and Damages \$3,516,000
02 RELOCATIONS		
Item 4 St. Johns Bayou	\$928,000	Item 2, Gravity Outlet and portion of Closure \$12,093,000
Item 4, Setback Levee Ditch	\$74,000	Item 2 New Madrid Floodway Closure \$2,592,000
Item 5, St. Johns Pumping Station	\$186,000	Setback Levee Raise \$8,121,720
Item 6, St. James Ditch	\$2,009,000	
TOTAL 02 Relocations	\$3,197,000	TOTAL Levees and Floodwalls \$22,806,720
02 CHANNELS AND CANALS		
Item 1	\$0	
Item 3, St. Johns Bayou	\$1,945,000	
Item 4, St. Johns and Setback Levee	\$2,118,000	
Item 5, St. Johns Bayou Pumping Station	\$1,356,000	
Item 6, St. James Ditch	\$947,000	
TOTAL 09 Channels and Canals	\$6,366,000	
13 Pumping Plants		
NMF Pumping Station	\$19,647,100	
NMF Seismic	\$1,964,710	
Item 5, St. Johns Bayou Pumping Station	\$17,861,000	
Seismic	\$1,786,100	
TOTAL 13 Pumping Stations	\$41,258,910	
30 PLANNING, ENGINEERING, and DESIGN		
NMF PED	\$756,413	
Phase 1 PED	\$980,000	
VE Study (Items 3, 4, and 6)	\$150,000	
VE Study (Items 2 and 5)	\$100,000	
TOTAL PED	\$1,986,413	
31 CONSTRUCTION MANAGEMENT		
NMF Pumping Station		
Item 2		\$807,675
Setback Levee Grade Raise		\$446,695
TOTAL S+A		\$1,254,370
TOTAL PHASE 1 ST. JOHNS BAYOU	\$63,048,973	TOTAL NMF Closure \$28,425,324.80
Mitigation & Monitoring		
Shorebirds	\$1,587,678	
Borrow Pits	\$72,563	
Buffer	\$1,218,422	
Reforestation	\$14,393,266	
Batture Land Reforestation	\$0	
Big Oak Tree State Park Resoration	\$0	
Floodplain Lake	\$0	
subtotal	\$17,271,928	
SJNM Adjustment (9%)	\$5,741,306	
Mitigation & Monitoring Total	\$23,013,234	Mitigation & Monitoring Total \$58,050,983
Adaptive Management and Monitoring	\$1,178,000	Adaptive Management and Monitoring \$4,712,000
TOTAL ALTERNATIVE 3.2	\$87,240,207.01	TOTAL ALTERNATIVE 3.2 \$91,188,307.56

Item Description	SJNM Feature	MRL Feature
01 LANDS AND DAMAGES		
Item 1	\$0	
Item 3, St. Johns Bayou (0.0 - 3.0)	\$931,000	Levee Closure \$48,000
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000	Setback Levee Grade Raise \$630,000
Item 5, St. Johns Bayou Pumping Station	\$728,000	Acquisition \$210,000
Item 6, St. James Ditch	\$1,310,000	waterfowl \$2,628,000
waterfowl	\$2,835,000	
TOTAL 01 Lands and Damages	\$6,793,000	TOTAL 01 Lands and Damages \$3,516,000
02 RELOCATIONS		
Item 4 St. Johns Bayou	\$928,000	Item 2, Gravity Outlet and portion of Closure \$12,093,000
Item 4, Setback Levee Ditch	\$74,000	Item 2 New Madrid Floodway Closure \$2,592,000
Item 5, St. Johns Pumping Station	\$186,000	Setback Levee Raise \$8,121,720
Item 6, St. James Ditch	\$2,009,000	
TOTAL 02 Relocations	\$3,197,000	TOTAL Levees and Floodwalls \$22,806,720
02 CHANNELS AND CANALS		
Item 1	\$0	
Item 3, St. Johns Bayou	\$1,945,000	
Item 4, St. Johns and Setback Levee	\$2,118,000	
Item 5, St. Johns Bayou Pumping Station	\$1,356,000	
Item 6, St. James Ditch	\$947,000	
TOTAL 09 Channels and Canals	\$6,366,000	
13 Pumping Plants		
NMF Pumping Station	\$19,647,100	
NMF Seismic	\$1,964,710	
Item 5, St. Johns Bayou Pumping Station	\$17,861,000	
Seismic	\$1,786,100	
TOTAL 13 Pumping Stations	\$41,258,910	
30 PLANNING, ENGINEERING, and DESIGN		
NMF PED	\$756,413	
Phase 1 PED	\$980,000	
VE Study (Items 3, 4, and 6)	\$150,000	
VE Study (Items 2 and 5)	\$100,000	
TOTAL PED	\$1,986,413	
31 CONSTRUCTION MANAGEMENT		
NMF Pumping Station		
Item 2		\$807,675
Setback Levee Grade Raise		\$446,695
TOTAL S+A		\$1,254,370
TOTAL PHASE 1 ST. JOHNS BAYOU	\$63,048,973	TOTAL NMF Closure \$28,425,324.80
Mitigation & Monitoring		
Shorebirds	\$1,587,678	
Borrow Pits	\$72,563	
Buffer	\$1,218,422	
Reforestation	\$14,393,266	
Batture Land Reforestation	\$0	
Big Oak Tree State Park Resoration	\$0	
Floodplain Lake	\$0	
subtotal	\$17,271,928	
SJNM Adjustment (9%)	\$3,304,852	
Mitigation & Monitoring Total	\$20,576,780	Mitigation & Monitoring Total \$33,415,723
Adaptive Management and Monitoring	\$1,178,000	Adaptive Management and Monitoring \$4,712,000
TOTAL ALTERNATIVE 4.1	\$84,803,752.78	TOTAL ALTERNATIVE 4.1 \$66,553,048.05

Item Description	SJNM Feature	MRL Feature
01 LANDS AND DAMAGES		
Item 1	\$0	
Item 3, St. Johns Bayou (0.0 - 3.0)	\$931,000	
Item 4, St. Johns Bayou and Setback Levee Ditch	\$989,000	
Item 5, St. Johns Bayou Pumping Station	\$728,000	
Item 6, St. James Ditch	\$1,310,000	
waterfowl	\$2,835,000	
TOTAL 01 Lands and Damages	\$6,793,000	\$64,553,150
02 RELOCATIONS		
Item 4 St. Johns Bayou	\$928,000	
Item 4, Setback Levee Ditch	\$74,000	
Item 5, St. Johns Pumping Station	\$186,000	
Item 6, St. James Ditch	\$2,009,000	
TOTAL 02 Relocations	\$3,197,000	\$22,806,720
02 CHANNELS AND CANALS		
Item 1	\$0	
Item 3, St. Johns Bayou	\$1,945,000	
Item 4, St. Johns and Setback Levee	\$2,118,000	
Item 5, St. Johns Bayou Pumping Station	\$1,356,000	
Item 6, St. James Ditch	\$947,000	
TOTAL 09 Channels and Canals	\$6,366,000	\$848,235
13 Pumping Plants		
NMF Pumping Station	\$19,647,100	
NMF Seismic	\$1,964,710	
Item 5, St. Johns Bayou Pumping Station	\$17,861,000	
Seismic	\$1,786,100	
TOTAL 13 Pumping Stations	\$41,258,910	\$807,675
30 PLANNING, ENGINEERING, and DESIGN		
NMF PED	\$756,413	
Phase 1 PED	\$980,000	
VE Study (Items 3, 4, and 6)	\$150,000	
VE Study (Items 2 and 5)	\$100,000	
TOTAL PED	\$1,986,413	\$446,695
31 CONSTRUCTION MANAGEMENT		
NMF S+A	\$1,188,650	
Phase 1, Supervision and Adminstration	\$2,259,000	
TOTAL S+A	\$3,447,650	\$1,254,370
TOTAL PHASE 1 ST. JOHNS BAYOU	\$63,048,973	\$89,462,474.80
Mitigation & Monitoring		
Shorebirds	\$1,587,678	
Borrow Pits	\$72,563	
Buffer	\$1,218,422	
Reforestation	\$14,393,266	
Batture Land Reforestation	\$0	
Big Oak Tree State Park Resoration	\$0	
Floodplain Lake	\$0	
subtotal	\$17,271,928	
SJNM Adjustment (9%)	\$355,063	
Mitigation & Monitoring Total	\$17,626,991	\$3,945,148
Adaptive Management and Monitoring	\$1,178,000	\$3,590,084
TOTAL ALTERNATIVE 4.2	\$81,853,964.30	\$3,590,084
Mitigation & Monitoring		
Shorebirds	\$3,933,898	
Borrow Pits	\$11,250	
Buffer	\$0	
Reforestation		
Batture Land Reforestation		
Big Oak Tree State Park Resoration		
Floodplain Lake		
subtotal		
SJNM Adjustment (9%)		
Mitigation & Monitoring Total	\$4,712,000	\$97,764,559.03
TOTAL ALTERNATIVE 4.2	\$81,853,964.30	\$97,764,559.03

Appendix C

Part 1

Hydraulics and Hydrology



**U.S. Army Corps of Engineers
Memphis District**

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APPENDIX C

HYDRAULICS & HYDROLOGY

INTRODUCTION

Authorized project improvements proposed under Memphis District General Design Memorandum 101 St. Johns Bayou and New Madrid Floodway Missouri Phase II (GDM 101) will tend to maintain lower water surface elevations than currently exist during certain months of the year in the sump areas of St. Johns Bayou and the New Madrid Floodway. A hydraulic analysis was performed by the Memphis District Hydraulics Branch for existing and authorized project conditions in St. Johns Bayou and for existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions in the New Madrid Floodway. The results of the analysis provide descriptive statistics required for the SEIS and are reported in this appendix.

BACKGROUND

Descriptive information of St. Johns Bayou and the New Madrid Floodway is provided below.

St. Johns Bayou

The St. Johns Bayou drainage basin is approximately 450 square miles in area and extends from Commerce and Benton, Missouri to New Madrid, Missouri (Plate 1). The basin has maximum dimensions of approximately 40 miles from north to south and approximately 25 miles from east to west. Under existing conditions the basin is separated from its natural outlet at the Mississippi River by levees. These levees form a sump and protect the southern portion of the basin interior from Mississippi River floodwaters (Plate 2). A gravity outlet consisting of six 10 ft x 10 ft box culverts extends through the Birds Point-New Madrid Setback Levee, permitting the basin to drain freely when the Mississippi River elevation is lower than the interior elevation. The existing sump ditch bottom is approximately 258 NGVD. Closure of the gates protects the interior from high Mississippi River stages. The existing gravity gate system was completed in 1953.

Runoff from intra-basin precipitation cannot drain by gravity during periods when the Mississippi River stage exceeds the interior water level. Under authorized project conditions a 1000 cfs pump station will be installed to permit removal of interior floodwater when the gravity outlets are closed against a high Mississippi River stage. The normal start and stop pump elevations will be 279 and 277 NGVD, respectively. During the waterfowl season the start and stop pump elevations will be 286 and 285 NGVD, respectively.

Operation of the project pump station from February through May will tend to maintain lower water surface elevations than currently exist in the sump area of St. Johns Bayou. During summer and fall

there will be little difference between existing and project conditions, since most drainage will still be gravity-flow through the existing gates. During December and January project water levels are expected to be higher due to intentional flooding of the sump area to promote waterfowl habitat.

To evaluate possible environmental impacts due to the lowered water levels expected in some months, an analysis was required. The approach taken was to perform a continuous simulation of interior water surface elevations for the period 1943-2009. The starting date of the simulation was 1 October, 1942.

New Madrid Floodway

The Birds Point-New Madrid Floodway was authorized by the Flood Control Act approved 15 May 1928. The Floodway is designed to convey part of the Mississippi River flow during extreme floods, thereby reducing stages at Cairo, Illinois. It has been operated twice, during the flood of 1937 and the flood of 2011. The Floodway extends from Birds Point to New Madrid and lies between the Birds Point-New Madrid Setback Levee and the Mississippi River Mainline Levee (Plate 1).

The Floodway drainage basin created by the surrounding levees has an area of approximately 183 square miles (Plate 1). The Floodway has a maximum length of about 30 miles from northeast to southwest and a maximum width of approximately 10 miles from northwest to southeast.

Unlike St. Johns Bayou, the New Madrid Floodway under existing conditions is subject to flooding from the Mississippi River. Levees completely surround and protect the Floodway, except at the Floodway outlet at New Madrid. The 1500 ft wide opening at New Madrid serves as an outlet during Floodway operation. Since operation of the Floodway is a rare event, the normal function of the opening is to provide a drainage outlet for the Floodway basin. Mud Ditch is the stream emerging from the Floodway outlet, with a bottom elevation of 261.23 NAVD. However, during high Mississippi River stages at New Madrid, the opening admits floodwaters from the river into the interior of the Floodway. Note that elevations in this document are related to NAVD in the New Madrid Floodway and to NGVD in St. Johns Bayou to properly correlate to the topographic data generated for the respective basins.

Under authorized project conditions the 1500 ft opening will be closed, forming a sump. A gravity outlet with an invert elevation of 261.23 NAVD and a 1500 cfs pump station will be installed to permit operation comparable to that proposed for St. Johns Bayou. The normal start and stop pump elevations will be 278.23 and 275.23 NAVD, respectively. During the 1 December to 31 January waterfowl season, the start and stop pump elevations will be 285.63 and 284.63 NAVD, respectively. The Floodway project results in a more significant change in interior stage-durations than for St. Johns Bayou, because the Floodway at New Madrid will be converted from an existing condition without backwater protection to a project condition of protection provided by levees and pumps. A continuous simulation was performed for the Floodway for the period 1943-2009, comparable to the analysis performed for St. Johns Bayou.

Three additional alternative projects were also analyzed for the New Madrid Floodway and are referred to as alternative 3.1, alternative 3.2, and alternative 4. These alternative projects differ from the authorized project with respect to higher normal start and stop pump elevations and changes in gate closing elevations to increase fish access availability into and out of the Floodway during fish spawning and rearing season. The alternative 3.1 project analysis presented in this appendix is based on start pump, stop pump, and gate closing elevations as follows:

- (1) For the period from 15 November through 28 February, start pump, stop pump, and gate closing elevations are 289.5, 288.5, and 288.0 NAVD88, respectively.
- (2) For the period from 1 March through 15 April, start pump, stop pump, and gate closing elevations are 288.0, 287.0, and 286.0 NAVD88, respectively.
- (3) For the period from 16 April through 30 May, start pump, stop pump, and gate closing elevations are 284.0, 282.0, and 284.0 NAVD88, respectively.
- (4) For the period from 1 June through 14 November, start pump, stop pump, and gate closing elevations are 280, 278.5, and 278.5 NAVD88, respectively.

The alternative 3.2 project analysis presented in this appendix is based on start pump, stop pump, and gate closing elevations as follows:

- (1) For the period from 15 November through 28 February, start pump, stop pump, and gate closing elevations are 289.5, 288.5, and 288.0 NAVD88, respectively.
- (2) For the period from 1 March through 15 April, start pump, stop pump, and gate closing elevations are 286.0, 285.0, and 284.0 NAVD88, respectively.
- (3) For the period from 16 April through 30 May, start pump, stop pump, and gate closing elevations are 282.0, 280.0, and 282.0 NAVD88, respectively.
- (4) For the period from 1 June through 14 November, start pump, stop pump, and gate closing elevations are 280, 278.5, and 278.5 NAVD88, respectively.

The alternative 4 project analysis presented in this appendix is based on start pump, stop pump, and gate closing elevations that do not change throughout the year and are 289.5, 288.5, and 288.0 NAVD88, respectively.

The St. Johns Bayou basin and the Floodway basin have a common outlet to the Mississippi River downstream of the proposed pump stations. The authorized pump stations for St. Johns Bayou and the New Madrid Floodway are about 0.2 miles apart (Plate 1). Mud Ditch joins St. Johns Bayou immediately downstream of the authorized pump stations. From the mouth of Mud Ditch to the Mississippi River, the final reach of St. Johns Bayou is approximately 0.5 miles long. The New Madrid gage is located approximately 0.3 miles downstream of the mouth of St. Johns Bayou.

METHOD

The descriptive statistics reported herein are based on a continuous simulation of the respective basins for the period 1943-2009. Neither St. Johns Bayou nor the Floodway have gage records

suitable for this analysis. Therefore, synthetic elevations were generated for the basins, which were compared to observed elevations on the Mississippi River at New Madrid.

Data

Basic data available for the study included Mississippi River elevations, rainfall, topography, and land cover. Mississippi River stage data at New Madrid was used for the period-of-record. Period-of-record rainfall data were available for the nearby towns of New Madrid, Missouri, Cairo, Illinois, and Sikeston, Missouri. Original study elevation-area curves based on conventional topographic mapping were available, as well as LIDAR-based curves prepared specifically for this analysis.

Wetland elevation in the sump areas of St. Johns Bayou and the New Madrid Floodway was computed based on continuous duration of flooding in the growing season. The *Analysis of Sump Daily Elevations* section describes wetland elevation calculations and the 14 day duration elevation used in the current legal wetland definition.

Determination of Daily Sump Elevations

St. Johns Bayou and the New Madrid Floodway were studied separately. For both basins it was necessary to develop a continuous synthetic record of daily sump elevations for 1943-2009. During the original development of GDM 101, hydrologic and hydraulic models were developed which served as the basis for design. These same models were the basis of the daily elevations used for existing and project conditions in the current analysis.

Synthetic daily inflows to the sump were calculated using the computer program HUXRAIN. The program uses the Antecedent Precipitation Index (API) method to estimate runoff from rainfall (see Appendix C Part 2). The rainfall data recorded at New Madrid, Cairo, and Sikeston were prorated by Thiessen polygons to estimate intra-basin rainfall depths. A pump-simulation computer program used the HUXRAIN synthetic daily inflows, the Mississippi River elevation, and information describing operation of the gravity outlet and pump station to calculate daily elevations at the sump.

St. Johns Bayou - For the existing conditions simulation, it was assumed that the gravity gates at the outlet structure would be operated to minimize interior stages throughout the period-of-record. Under project conditions waterfowl habitat will be maintained in December and January. During December and January, the simulation modeled flashboards with a crest elevation of 284.0 NGVD, which tended to maintain a minimum pool for waterfowl.

New Madrid Floodway - Under existing conditions there is no provision to control water surface elevation in the sump area. The daily elevation is either the elevation of the Mississippi River at New Madrid or the elevation associated with Mud Ditch discharge, whichever is higher.

Under project conditions the determination of daily sump elevation was made comparable to that for St. Johns Bayou. During December and January, the simulation modeled flashboards with a crest elevation of 283.0 NAVD, which tended to maintain a minimum pool for waterfowl.

Analysis of Daily Sump Elevations

Three types of hydrologic evaluation were performed for the analysis--wetland elevation, waterfowl habitat elevation, and fish habitat acreage.

1. Wetland Elevation - One criterion in the determination of nonagricultural wetlands is the degree of continuous inundation during the growing season. The growing season used in the analysis is 20 March to 11 November (237 days). According to current U. S. Army Corps of Engineers wetland policy, nonagricultural areas that are continuously inundated or saturated less than 14 days of the growing season are defined as non-wetlands. Those nonagricultural areas that are continuously inundated or saturated at least 14 days during the growing season may be wetlands, depending on the soil type and vegetation present. For each year in the simulation period, the highest 14 day duration elevations during the growing season were determined in the sump area. The median value of these annual maxima was taken as the effective 14 day duration elevation.

The computer program WETSORT was used to perform the statistical analyses for determination of wetland elevations due to continuous inundation. For each year of the period-of-record, WETSORT identified the span of consecutive days within the growing season having the highest minimum elevation and reported that minimum elevation. For example, the procedure used to determine the 14 day duration for existing conditions in St. Johns Bayou sump was as follows: The growing season in the project area was defined as 20 March to 11 November. For the period-of-record 1943-2009 (67 years), WETSORT identified for each year of the growing season the span of 14 consecutive days in St. Johns Bayou sump having the highest minimum elevation and reported that minimum elevation. WETSORT ranked each of the reported elevations in descending order. The median elevation determined from this group of 67 elevations was 287.1. This process was repeated for authorized project conditions in the St. Johns Bayou sump and for existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions in the New Madrid Floodway.

The daily water surface elevations input to WETSORT were based on the combined effects of Mississippi River stages, local runoff events, and project operations, such as gate closure and pumping, if applicable. The daily water surface elevations do not account for wetland areas such as isolated shallow depressions that hold water under existing and project conditions for extended periods of time after inundation occurs.

2. Waterfowl Habitat Elevation - Evaluation of waterfowl habitat was performed by others for St. Johns Bayou existing and authorized project conditions and for the New Madrid Floodway existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions. These evaluations were based on estimates of the habitat acreage available during the applicable season. Habitat acreage is dependent on the sump elevation-area relationship and elevation hydrograph. The

daily sump elevations prepared for this study were used as input to WETSORT for three waterfowl periods: November, December-January, and February-March. For this analysis, a span of three consecutive days for each waterfowl period for each year of the period-of-record was used. For each group of 67 elevations determined for each of the waterfowl periods that occurred during the period-of-record for existing and authorized project conditions in the St. Johns Bayou sump and for existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions in the New Madrid Floodway, a frequency analysis was performed. The frequency analysis determined the elevations with a 99, 50, 20, 10, 4, 2, and 1 percent chance of annual exceedence, presented as the 1.01, 2, 5, 10, 25, 50, and 100 year return periods, respectively.

3. Fish Habitat Acreage - Evaluation of fish habitat was performed by others for St. Johns Bayou existing and authorized project conditions and for the New Madrid Floodway existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions. These evaluations were based on estimates of the habitat acreage available during the 01 March-31 March early season, the 01 April-15 May mid-season, and the 16 May-30 June late season. Habitat acreage is dependent on the sump elevation-area relationship and elevation hydrograph. The daily sump elevations prepared for this study were used as input to a computer program to obtain estimates of habitat acreage. Habitat was also considered to be affected by the 2-yr and 5-yr frequency elevations, shown in Table 1. Note that the 2-yr frequency elevation has a 50 percent chance of annual exceedence, and the 5-yr frequency elevation has a 20 percent chance of annual exceedence.

Table 1 2-Yr and 5-Yr Frequency Sump Elevations

Project Area	Condition	2-yr Freq. Elev, ft	5-yr Freq. Elev, ft
St. Johns Bayou	Existing	291.0	294.1
	Authorized Project	290.4	292.6
New Madrid Floodway	Existing	292.1	296.6
	Authorized Project	285.7	286.5
	Alternative 3.1	287.6	288.7
	Alternative 3.2	287.2	288.3
	Alternative 4	288.5	289.6

Fish spawning and rearing habitat acreage was estimated using the computer program EnviroFish. Data required by the program consisted of the minimum number of days needed to compute available spawning habitat and maximum and minimum water depths, as shown in Table 2. Note that agricultural and fallow land were the only land use categories that were evaluated as spawning

habitat; all other land uses were evaluated as rearing habitat, which does not require a duration value. The beginning and ending years of the simulation period (1943-2009), the beginning and ending dates of the season, the HEC-DSSVue pathname of daily elevations, and the HEC-DSSVue pathname of daily water surface acreages were also required. The sump area was divided into land use categories for fish habitat. Although the EnviroFish program does not use food-source data, the land use categories serve to describe the surfaces available for spawning and rearing.

**Table 2 EnviroFish Input Data
by Land Use Category**

Item	Agri. Land	Developed Land	Fallow Land	Forested Land	Herbaceous Land	Open Water Bodies	Pasture Land	Scrub/ Shrub Land
	acres	Acres	acres	acres	acres	acres	acres	acres
Season	Early	01Mar -31Mar	01Mar -31Mar	01Mar -31Mar	01Mar -31Mar	01Mar -31Mar	01Mar -31Mar	01Mar -31Mar
		01Apr -15May	01Apr -15May	01Apr -15May	01Apr -15May	01Apr -15May	01Apr -15May	01Apr -15May
	Late	16May -30Jun	16May -30Jun	16May -30Jun	16May -30Jun	16May -30Jun	16May -30Jun	16May -30Jun
Duration, days	8	NA	8	NA	NA	NA	NA	NA
Max Water Depth, ft	99	99	99	99	99	99	99	99
Min Water Depth, ft	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0

ANALYSIS RESULTS

St. Johns Bayou - St. Johns Bayou water surface elevations are affected by existing and authorized project conditions. Project elevations may be higher during December and January due to intentional flooding of the interior; late winter and spring elevations are lowered for agricultural requirements; summer and fall elevations are only slightly lower than existing conditions. The results of the St. Johns Bayou sump analysis are presented graphically in Plates 3-72. Plates 3-70 present yearly plots (1942-2009) of existing and authorized project conditions for interior pool water surface elevations. Plate 71 presents a 365-day plot of interior pool elevation maxima, means, medians, and minima for the simulation period under existing conditions. Plate 72 presents a 365-day plot of interior pool elevation maxima, means, medians, and minima for the simulation period under authorized project conditions.

Wetland Elevation - It is estimated that for authorized project conditions the 14 day limiting nonagricultural wetland elevation will decrease 4.4 ft (Table 3).

**Table 3 Wetland Elevation 1943-2009
St. Johns Bayou Sump**

Evaluation Type:	Existing Conditions	Authorized Project Conditions
	No Pump	1000 cfs Pump
	Elev, ft NGVD	Elev, ft NGVD
Wetland Elevation (20Mar-11 Nov)		
14 day duration	287.1	282.7

Waterfowl Habitat Elevation - Table 4 presents the waterfowl elevations for existing and authorized project conditions in the sump area of St. Johns Bayou. Authorized project elevations are a maximum of 2.6 feet lower than corresponding existing elevations during November for the 5 year return period. During the December-January waterfowl period, authorized project elevations are higher than existing elevations for the 1.01, 2, 5, and 10 year return periods, with a maximum difference of 24.2 feet for the 1.01 year return period; authorized project elevations are lower than existing elevations for the 25, 50, and 100 year return periods. Authorized project elevations are a maximum 2.9 feet lower than existing elevations during February-March for the 100 year return period.

Table 4 Waterfowl Elevation 1943-2009
St. Johns Bayou Sump

Return Period	November	November	Dec-Jan	Dec-Jan	Feb-Mar	Feb-Mar
	Existing Conditions No Pump	Authorized Project Conditions 1000 cfs Pump	Existing Conditions No Pump	Authorized Project Conditions 1000 cfs Pump	Existing Conditions No Pump	Authorized Project Conditions 1000 cfs Pump
Years	Elev, ft NGVD	Elev, ft NGVD	Elev, ft NGVD	Elev, ft NGVD	Elev, ft NGVD	Elev, ft NGVD
1.01	258.0	258.0	260.8	285.0	269.3	267.4
2	272.6	270.8	284.6	288.5	287.9	286.6
5	279.9	277.3	288.2	290.3	291.4	289.7
10	282.8	280.8	290.2	291.2	293.4	291.3
25	284.9	284.1	292.3	292.2	295.5	293.2
50	285.6	284.7	293.8	292.8	297.0	294.4
100	286.4	285.4	295.1	293.3	298.3	295.4

Fish Habitat Acreage - The summary habitat acreage values for the entire simulation period in the sump area of St. Johns Bayou are presented in Table 5 for current land use and in Table 6 for future land use. Indicated existing fish habitat acreages were greatest on agricultural land and forested land. Lesser acreages were obtained for developed land, fallow land, herbaceous land, open water bodies, and pasture land. The scrub/shrub land acreage was zero. Fish habitat acreages will be reduced under project conditions. The reduction is typically on the order of forty percent.

Data shown in the tables for the three time periods are not additive, e.g. the three period results should not be added to obtain a total yearly acreage for a given land use.

Table 5 Fish Habitat Acreage
Current Land Use
St. Johns Bayou

Item	Agri.	Developed	Fallow	Forested	Herbaceous	Open	Pasture	Scrub/
	Land	Land	Land	Land	Land	Water	Land	Shrub
	acres	acres	acres	acres	Acres	Acres	acres	Land
01Mar-31Mar								
Existing	1054.6	59.5	39.9	1085.8	46.2	119.4	2.9	0.0
Authorized Project	588.0	32.7	25.7	726.1	30.1	91.4	1.0	0.0
01Apr-15May								
Existing	1043.7	67.5	40.2	1156.3	49.4	120.5	3.9	0.0
Authorized Project	563.7	35.3	24.0	739.5	30.9	90.6	1.2	0.0
16May-30Jun								
Existing	369.5	27.2	12.4	518.2	21.7	64.6	1.5	0.0
Authorized Project	139.2	13.8	5.3	278.5	11.2	44.1	0.5	0.0

Table 6 Fish Habitat Acreage
Future Land Use
St. Johns Bayou

Item	Agri. Land	Developed Land	Fallow Land	Forested Land	Herbaceous Land	Open Water Bodies	Pasture Land	Scrub/ Shrub Land
	acres	acres	acres	acres	Acres	acres	acres	acres
01Mar-31Mar								
Existing	904.8	59.5	39.9	1263.3	96.9	144.8	2.9	0.0
Authorized Project	493.5	32.7	25.7	836.2	61.5	107.1	1.0	0.0
01Apr-15May								
Existing	892.5	67.5	40.2	1357.4	106.9	149.2	3.9	0.0
Authorized Project	474.7	35.3	24.0	855.8	64.2	107.2	1.2	0.0
16May-30Jun								
Existing	322.7	27.2	12.4	598.6	44.7	76.1	1.5	0.0
Authorized Project	119.6	13.8	5.3	318.1	22.5	49.7	0.5	0.0

New Madrid Floodway - New Madrid Floodway water surface elevations are affected by existing, authorized, alternative 3.1, alternative 3.2, and alternative 4 project conditions. The results of the New Madrid Floodway analysis are presented graphically in Plates 73-145. Plates 73-140 present yearly plots (1942-2009) of existing, authorized project, and alternative project conditions for interior pool water surface elevations. Plate 141 presents a 365-day plot of interior pool elevation maxima, means, medians, and minima for the simulation period under existing conditions. Plate 142, Plate 143, Plate 144, and Plate 145 present 365-day plots of interior pool elevation maxima, means, medians, and minima for the simulation period for the authorized project, alternative 3.1, alternative 3.2, and alternative 4, respectively.

Wetland Elevation - The wetland elevation for alternative 3.1 is 0.5 ft higher than alternative 3.2 and 7.6 ft higher than the authorized project (Table 7). The wetland elevation for alternative 4 is 0.6 ft lower than existing conditions.

Table 7 Wetland Elevation 1943-2009
New Madrid Floodway Sump

Evaluation Type:	Existing Conditions Open & No Pump	Authorized Project Conditions Closure & 1500 cfs Pump	Alt. 3.1 Project Conditions Closure & 1500 cfs Pump	Alt. 3.2 Project Conditions Closure & 1500 cfs Pump	Alt. 4 Project Conditions Closure & 1500 cfs Pump
	Elev, Ft NAVD	Elev, Ft NAVD	Elev, Ft NAVD	Elev, Ft NAVD	Elev, Ft NAVD
Wetland Profile (20Mar-11 Nov)					
14 day duration	287.7	276.0	283.6	283.1	287.1

Waterfowl Habitat Elevation - Waterfowl elevations for existing and authorized project conditions in the sump area of the New Madrid Floodway are presented in Table 8. Authorized project elevations are a maximum of 2.6 feet lower than corresponding existing elevations during November for the 5 year return period. During the December-January waterfowl period, authorized project elevations are higher than existing elevations for the 1.01, 2, 5, and 10 year return periods, with a maximum difference of 21.1 feet for the 1.01 year return period; authorized project elevations are lower than existing elevations for the 25, 50, and 100 year return periods. Authorized project elevations are a maximum 2.9 feet lower than existing elevations during February-March for the 100 year return period.

Table 8 Waterfowl Elevation 1943-2009
New Madrid Floodway Sump

Return Period	November	November	Dec-Jan	Dec-Jan	Feb-Mar	Feb-Mar
	Existing Conditions Open & No Pump	Authorized Project Conditions Closure & 1500 cfs Pump	Existing Conditions Open & No Pump	Authorized Project Conditions Closure & 1500 cfs Pump	Existing Conditions Open & No Pump	Authorized Project Conditions Closure & 1500 cfs Pump
Years	Elev, ft NAVD	Elev, ft NAVD	Elev, ft NAVD	Elev, ft NAVD	Elev, ft NAVD	Elev, ft NAVD
1.01	262.8	262.4	262.9	284.0	275.3	267.2
2	272.1	270.5	282.1	285.5	288.5	281.0
5	276.9	275.5	289.0	286.2	293.4	282.8
10	279.3	278.5	292.9	286.5	296.0	283.9
25	282.0	280.5	297.1	286.9	298.4	285.0
50	283.8	281.2	299.5	287.1	299.9	285.8
100	285.4	281.7	301.9	287.3	301.4	286.4

Table 9 presents the waterfowl elevations for alternative 3.1 and alternative 3.2. To the nearest 0.1 feet, no difference is indicated between the alternative 3.1 and alternative 3.2 November and December-January waterfowl periods. During the February-March waterfowl period, alternative 3.1 elevations are a maximum 0.5 feet higher than alternative 3.2 elevations for the 5 year return period.

Table 9 Waterfowl Elevation 1943-2009
New Madrid Floodway Sump

Return Period	November	November	Dec-Jan	Dec-Jan	Feb-Mar	Feb-Mar
	Alt. 3.1 Project Conditions Closure & 1500 cfs Pump	Alt. 3.2 Project Conditions Closure & 1500 cfs Pump	Alt. 3.1 Project Conditions Closure & 1500 cfs Pump	Alt. 3.2 Project Conditions Closure & 1500 cfs Pump	Alt. 3.1 Project Conditions Closure & 1500 cfs Pump	Alt. 3.2 Project Conditions Closure & 1500 cfs Pump
Years	Elev, ft NAVD					
1.01	262.4	262.4	284.0	284.0	275.3	275.3
2	271.5	271.5	286.2	286.2	286.1	285.7
5	276.9	276.9	287.4	287.4	288.5	288.0
10	279.3	279.3	288.0	288.0	289.3	289.0
25	282.0	282.0	288.5	288.5	289.9	289.6
50	283.1	283.1	288.9	288.9	290.3	290.0
100	283.9	283.9	289.3	289.3	290.7	290.4

Table 10 presents the waterfowl elevations for alternative 4. To the nearest 0.1 feet, alternative 4 elevations are a maximum 0.1 feet higher than alternatives 3.1 and alternative 3.2 during the November waterfowl period. No difference is indicated between alternative 3.1, alternative 3.2, and alternative 4 for the December-January waterfowl period. During the February-March waterfowl period, alternative 4 elevations are a maximum 1.1 feet higher than alternative 3.1 elevations for the 50 year and 100 year return periods.

Table 10 Waterfowl Elevation 1943-2009
New Madrid Floodway Sump

Return Period	November	Dec-Jan	Feb-Mar
	Alt. 4 Project Conditions Closure & 1500 cfs Pump	Alt. 4 Project Conditions Closure & 1500 cfs Pump	Alt. 4 Project Conditions Closure & 1500 cfs Pump
Years	Elev, ft NAVD	Elev, ft NAVD	Elev, ft NAVD
1.01	262.4	284.0	275.3
2	271.6	286.2	286.5
5	277.0	287.4	289.1
10	279.4	288.0	290.3
25	282.0	288.5	290.9
50	283.1	288.9	291.4
100	284.0	289.3	291.8

Fish Habitat Acreage - The summary habitat acreage values for the entire simulation period in the sump area of the New Madrid Floodway are presented in Table 11 for current land use and in Table 12 for future land use. Indicated existing fish habitat acres were greatest on agricultural land and forested land. Lesser acreages were obtained for developed land, fallow land, herbaceous land, open water bodies, pasture land, and scrub/shrub land. The program indicates that fish habitat acreages will be reduced under project conditions. Program output indicates alternative 3.1 will typically maintain about ten times the habitat acreage as the authorized project and that alternative 3.2 will typically maintain six to seven times the habitat acreage as the authorized project.

As stated above, the three period results should not be summed to obtain a total yearly acreage for a given land use.

Table 11 Fish Habitat Acreage
Current Land Use
New Madrid Floodway

Item	Agri.	Developed	Fallow	Forested	Herbaceous	Open	Pasture	Scrub/
	Land	Land	Land	Land	Land	Water	Land	Shrub
	acres	acres	acres	acres	acres	Acres	acres	acres
01Mar-31Mar								
Existing	3124.6	105.3	21.2	1462.4	285.2	137.1	2.6	0.3
Authorized Project	34.0	0.5	2.4	81.9	13.0	17.3	0.0	0.0
Alternative 3.1	802.4	18.3	9.4	881.3	274.7	94.1	0.4	0.1
Alternative 3.2	450.2	9.2	5.2	567.5	272.3	83.4	0.3	0.0
Alternative 4	1209.9	25.9	11.4	1062.3	275.8	100.5	0.4	0.2
01Apr-15May								
Existing	3009.8	108.2	22.9	1523.3	277.1	145.7	2.5	0.4
Authorized Project	21.0	0.2	2.4	73.2	13.3	16.8	0.0	0.0
Alternative 3.1	374.9	10.0	5.7	586.4	254.5	74.6	0.3	0.1
Alternative 3.2	154.3	3.6	3.9	342.8	195.1	58.5	0.2	0.0
Alternative 4	1286.0	29.2	11.7	1136.5	265.8	101.5	0.4	0.2
16May-30Jun								
Existing	927.9	49.1	10.1	679.6	142.8	74.1	1.1	0.2
Authorized Project	13.8	0.1	1.6	52.4	5.6	11.4	0.0	0.0
Alternative 3.1	29.9	0.6	2.0	123.7	69.1	24.8	0.1	0.0
Alternative 3.2	17.4	0.3	2.0	105.0	38.7	21.0	0.0	0.0
Alternative 4	447.5	12.4	5.0	534.0	138.3	52.8	0.2	0.1

**Table 12 Fish Habitat Acreage
Future Land Use
New Madrid Floodway**

Item	Agri. Land	Developed Land	Fallow Land	Forested Land	Herbaceous Land	Open Water Bodies	Pasture Land	Scrub/ Shrub Land
	acres	acres	acres	acres	acres	Acres	acres	acres
01Mar-31Mar								
Existing	2906.4	105.3	21.2	1677.7	344.6	166.7	2.6	0.3
Authorized Project	11.7	0.5	2.4	112.2	15.6	18.5	0.0	0.0
Alternative 3.1	606.2	18.3	9.4	1074.4	327.8	120.7	0.4	0.1
Alternative 3.2	262.5	9.2	5.2	751.8	322.8	108.7	0.3	0.0
Alternative 4	1005.7	25.9	11.4	1260.6	330.3	127.8	0.4	0.2
01Apr-15May								
Existing	2801.8	108.2	22.9	1734.8	335.0	174.7	2.5	0.4
Authorized Project	1.5	0.2	2.4	102.8	15.6	18.0	0.0	0.0
Alternative 3.1	227.0	10.0	5.7	757.8	301.0	97.9	0.3	0.1
Alternative 3.2	67.7	3.6	3.9	467.4	228.3	75.0	0.2	0.0
Alternative 4	1087.3	29.2	11.7	1333.0	319.5	128.4	0.4	0.2
16May-30Jun								
Existing	839.1	49.1	10.1	787.5	170.9	88.2	1.1	0.2
Authorized Project	1.0	0.1	1.6	72.4	6.7	11.9	0.0	0.0
Alternative 3.1	1.1	0.6	2.0	178.8	81.2	30.8	0.1	0.0
Alternative 3.2	0.0	0.3	2.0	139.4	44.9	24.1	0.0	0.0
Alternative 4	359.3	12.4	5.0	638.7	165.5	66.5	0.2	0.1

Operation of the New Madrid Floodway

As a result of closure of the New Madrid Floodway under authorized and alternative project conditions, impacts to the flowlines for each condition were evaluated due to operation of the New Madrid Floodway. A description of each of the operation plans is included in Appendix K, Birds Point-New Madrid Floodway Operation.

Extensive model tests of the Mississippi River Levee system have been made to compare the current system response with that resulting from closing the existing gap at the lower end of the Floodway. Model test results are included in a report entitled "Transmittal of the Mississippi Basin Model Letter Report 89-1, Birds Point-New Madrid Floodway Reconnaissance Study," dated July 27, 1990. The report reflected steady-state Project Design Flood (PDF) tests and PDF hydrograph tests, considering the 1986 Plan of Operation of the New Madrid Floodway.

The results from the steady-state PDF tests comparing current conditions with and without the 1500-foot levee closure indicate very little difference in stages at Mississippi River gage locations. The only measured increases in stages with the closure were at Hickman, Kentucky and H.W. 173, which were 0.1 feet and 0.3 feet higher, respectively. A 0.1 feet decrease in stage was measured at the New Madrid gage for the test with the closure. The maximum increase in water surface elevation at stations along the riverside of the frontline levee was 0.5 feet at levee mile 81.

The results from the steady-state PDF tests show increases along the Birds Point-New Madrid Setback Levee due to closure of the 1500-foot gap. The increase in water surface elevation along the setback levee by closing the gap is presented in Table 13.

Table 13 Water Surface Elevation along Setback Levee

Levee Mile	Distance ft	Existing	Project	Difference
		Elev, ft NGVD	Elev, ft NGVD	
0	0	327.1	327.1	0.0
1	5215	326.9	326.9	0.0
2	10513	326.6	326.6	0.0
3	15801	325.7	325.9	0.2
4	21099	325.4	325.6	0.2
5	26309	325.0	325.2	0.2
6	31637	324.4	324.7	0.3
7	36929	322.4	322.7	0.3
8	42251	321.2	321.7	0.5
9	47563	320.3	320.9	0.6
10	52705	320.1	320.9	0.8
11	58017	319.1	320.2	1.1
12	63321	319.0	320.0	1.0
13	68621	318.8	319.9	1.1
14	73927	318.7	319.8	1.1
15	79119	318.6	319.8	1.2
16	84410	318.5	319.8	1.3
16.7	87984	318.2	319.5	1.3
17	89516	318.1	319.4	1.3
18	94634	318.0	319.3	1.3
19	99921	318.0	319.2	1.2
20	105123	317.9	319.1	1.2
20.3	106712	317.8	319.0	1.2
21	110421	317.8	319.0	1.2
22	115713	317.7	318.9	1.2
23	121012	317.6	318.8	1.2
24	126288	317.6	318.7	1.1
24.2	127327	317.3	318.4	1.1
25.5	134137	316.0	317.5	1.5
26	136789	315.9	317.4	1.5
27	142093	315.1	316.4	1.3
28	147504	315.1	316.4	1.3
29	152778	314.5	315.9	1.4
30	157984	314.0	315.4	1.4
31	163271	313.0	314.3	1.3
32	168666	312.0	313.2	1.2
33	174006	309.7	311.6	1.9
34	179300	308.8	311.6	2.8
35	181970	307.9	311.6	3.7
36	186117	307.7	307.7	0.0

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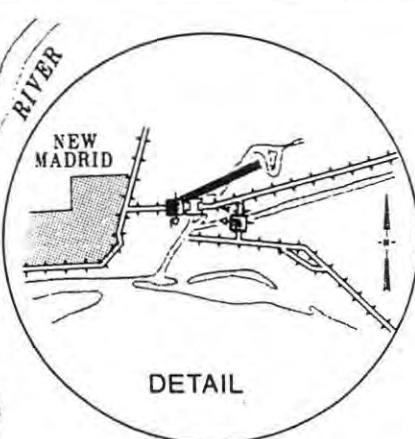
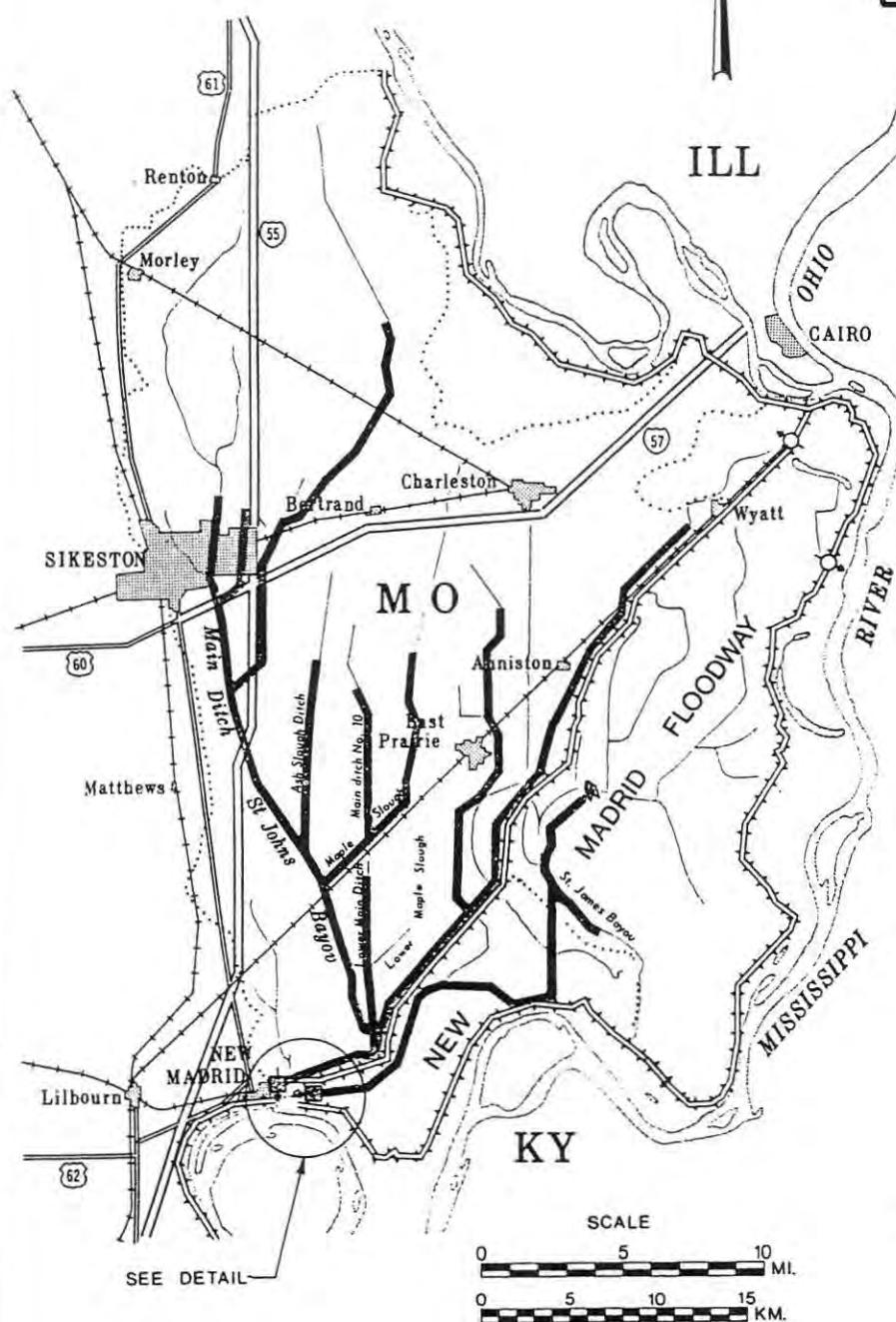
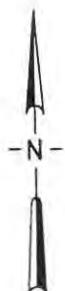
DSSVue. Hydrologic Engineering Center. U.S. Army Corps of Engineers. 2009.

Appendix K. Birds Point-New Madrid Floodway Operation. U.S. Army Corps of Engineers Memphis District. Undated.

Analysis of Potential Modification to the Plan of Operation for the Birds Point-New Madrid Floodway. U.S. Army Corps of Engineers Memphis District. 1985.

LEGEND

- | | | | |
|--|-------------------------|--|--------------------|
| | Project Levee | | Recommended |
| | Watershed Divide | | Under Construction |
| | Channel Plug | | Completed |
| | Pumping Station | | |
| | Outlet Structure | | |
| | Water Control Structure | | |
| | Gated Culvert | | |
| | Channels | | |

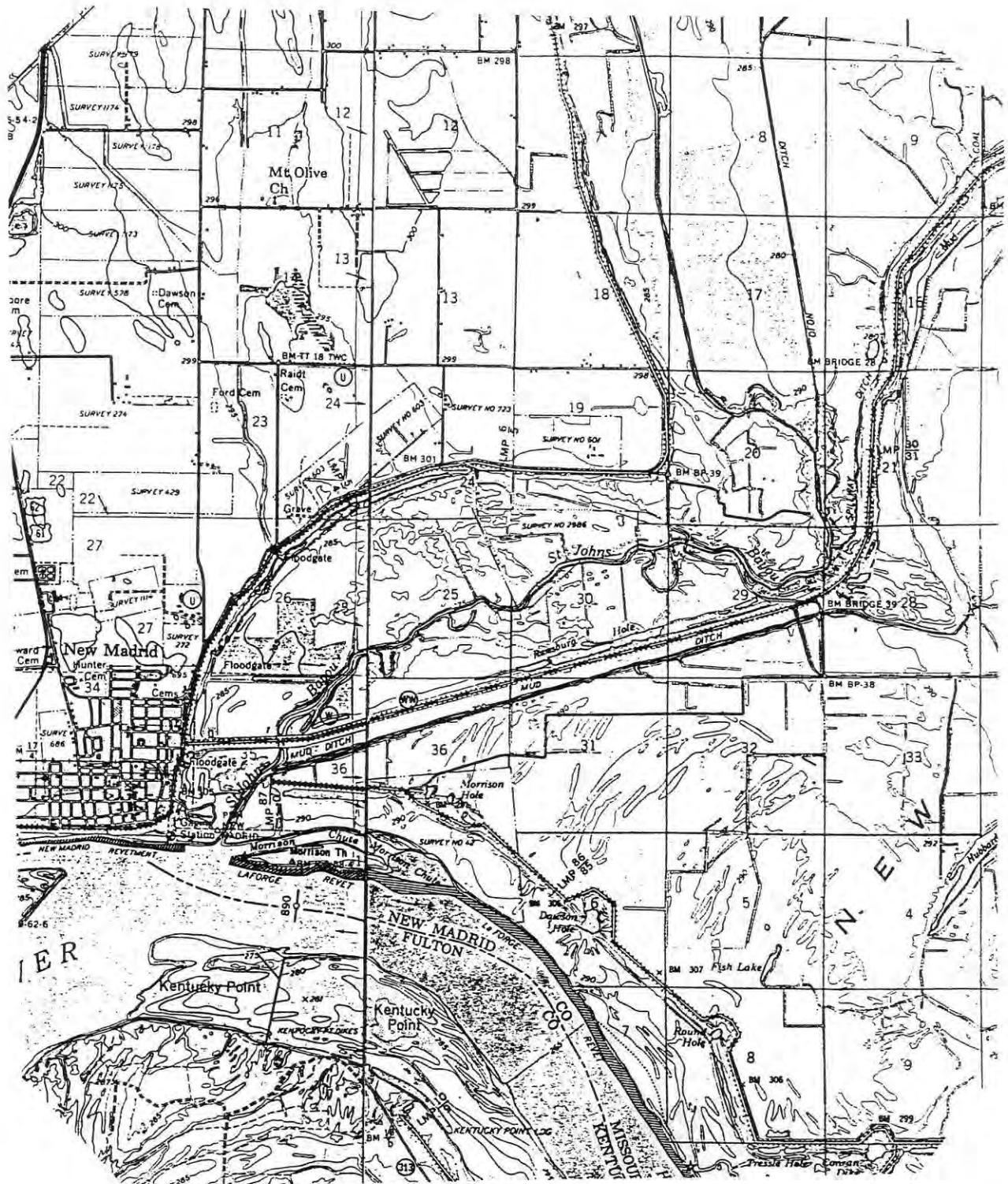


MISSISSIPPI RIVER COMMISSION
ST JOHNS BAYOU AND
NEW MADRID FLOODWAY MO.

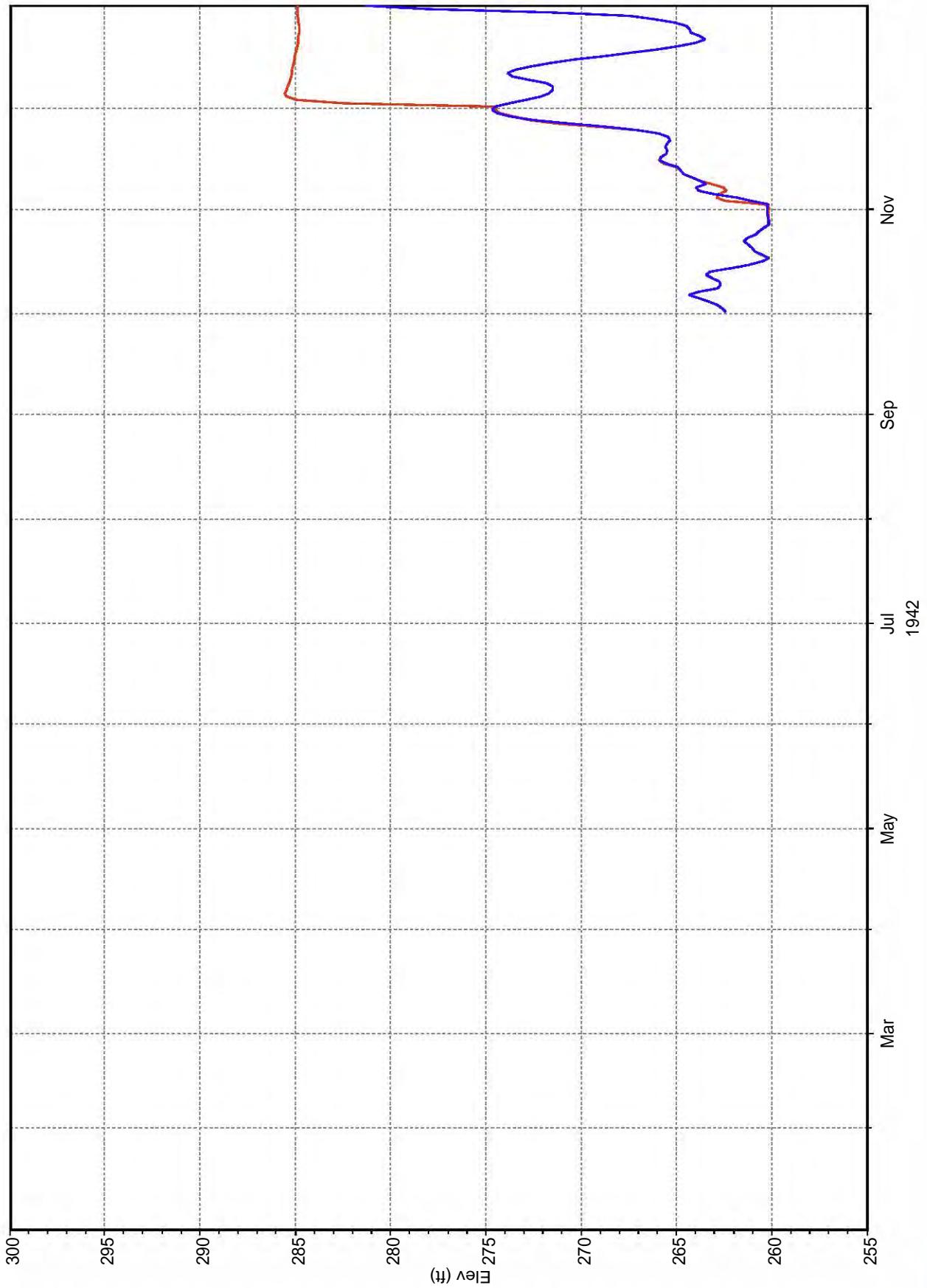
OFFICE OF THE DISTRICT ENGINEER
MEMPHIS, TENN.

30 SEPTEMBER 1985

PLATE 1

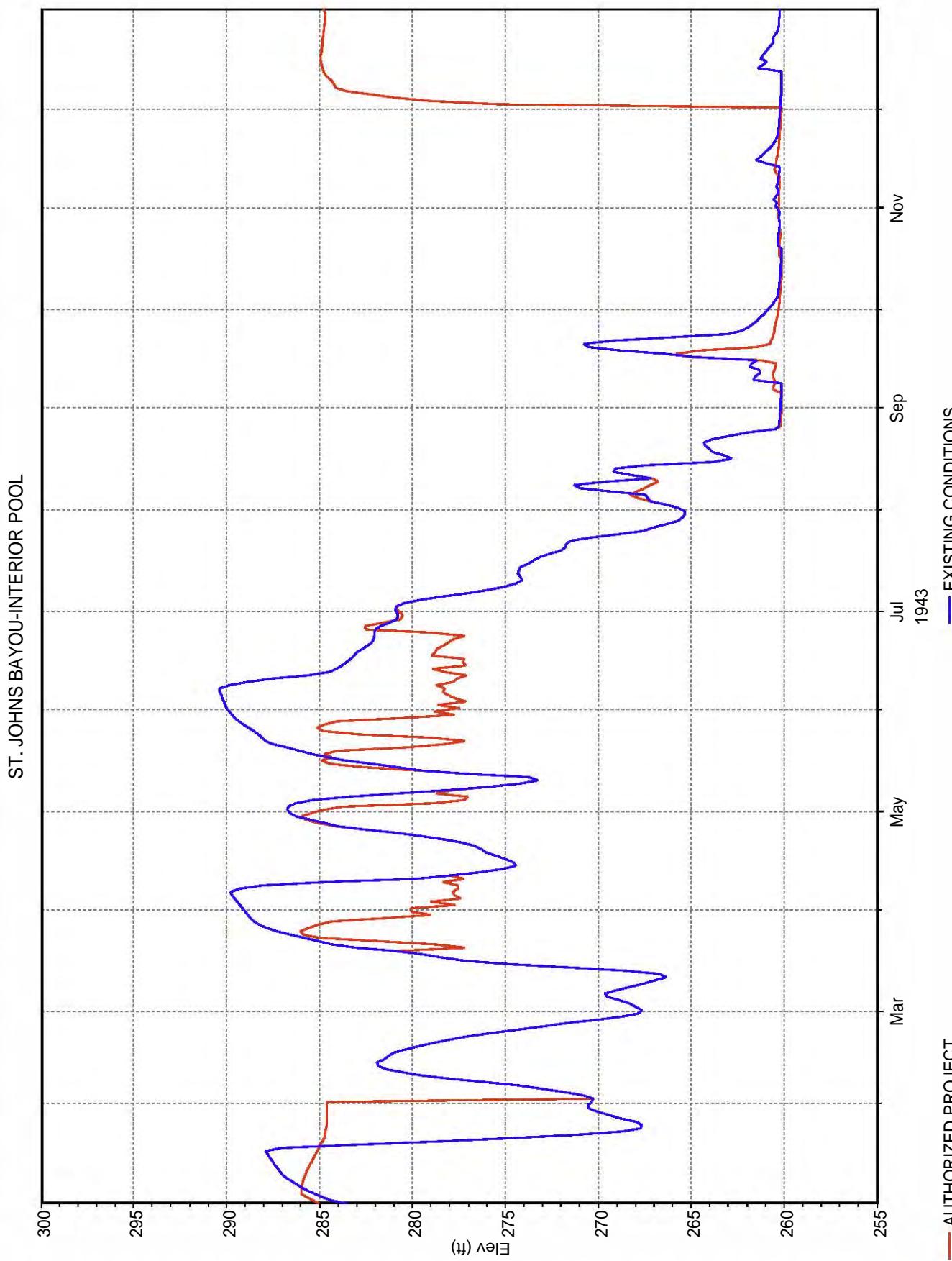


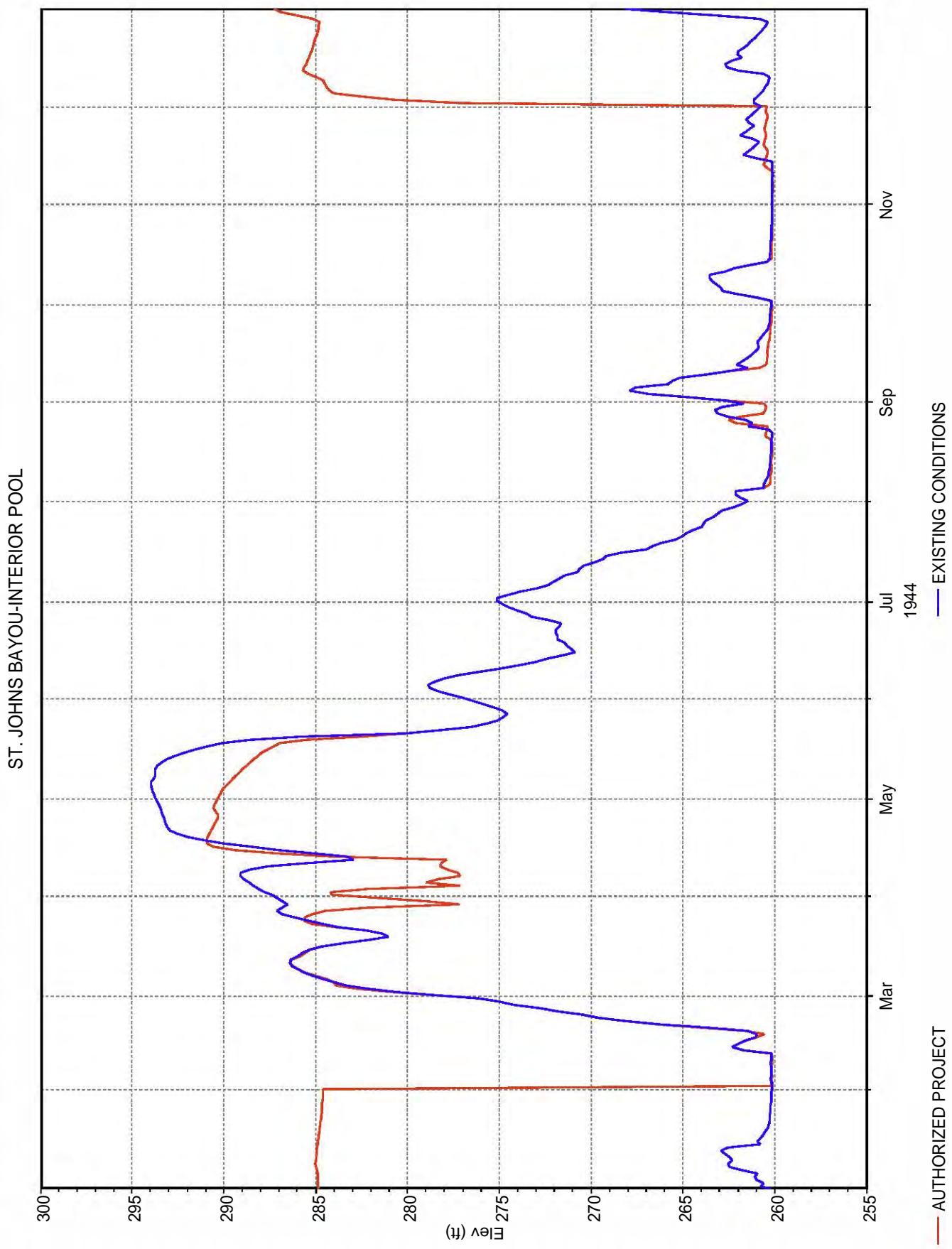
ST. JOHNS BAYOU-INTERIOR POOL

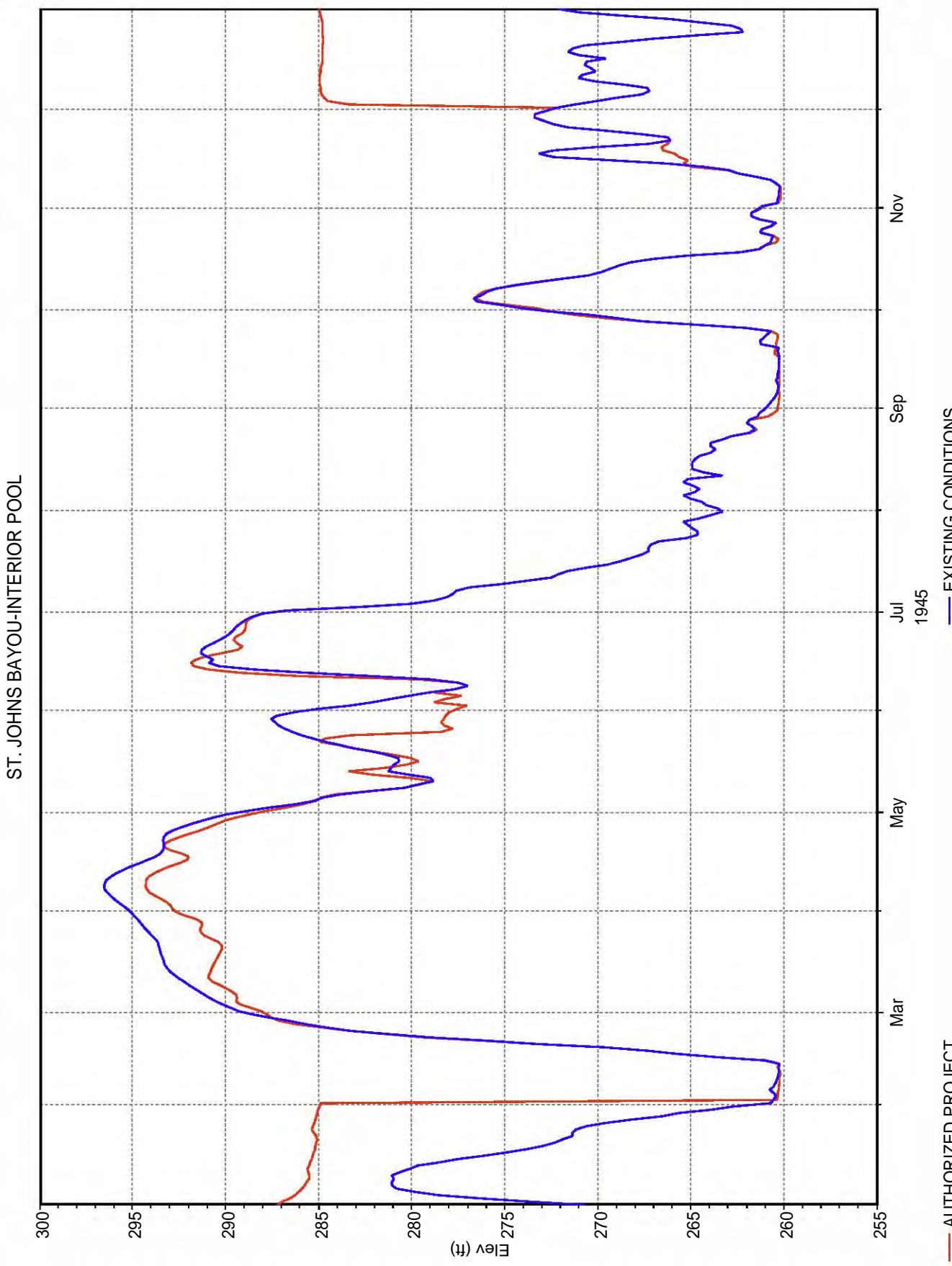


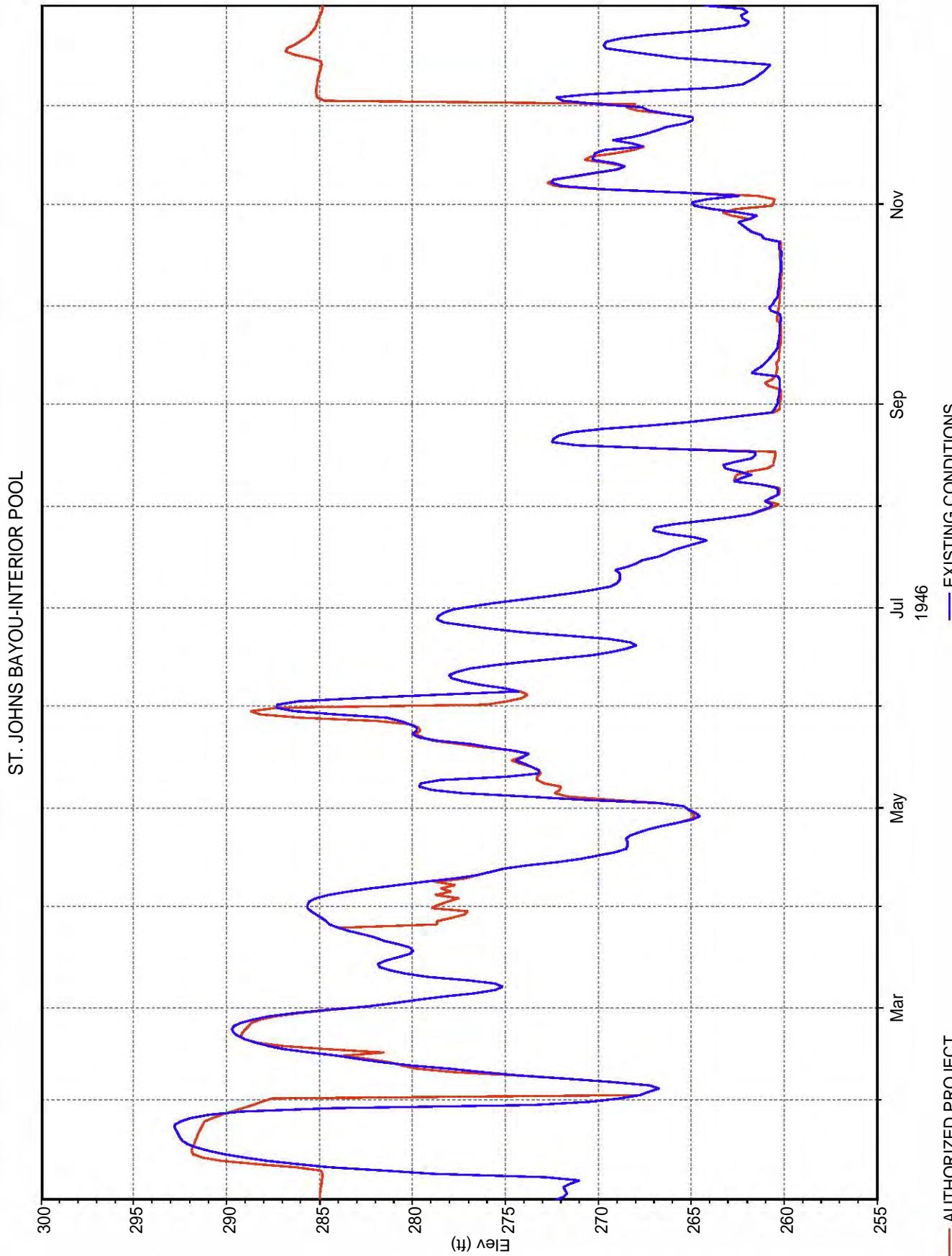
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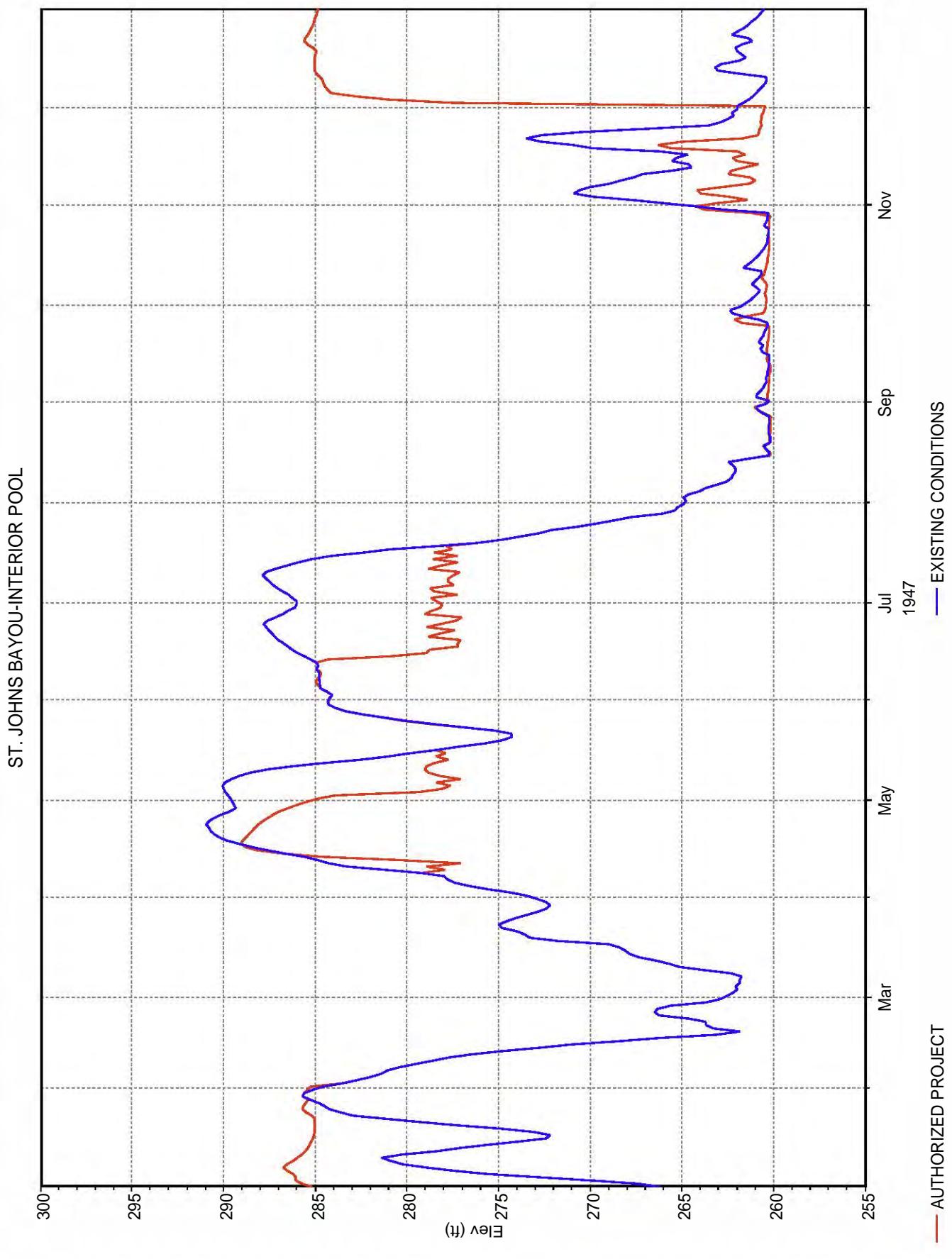
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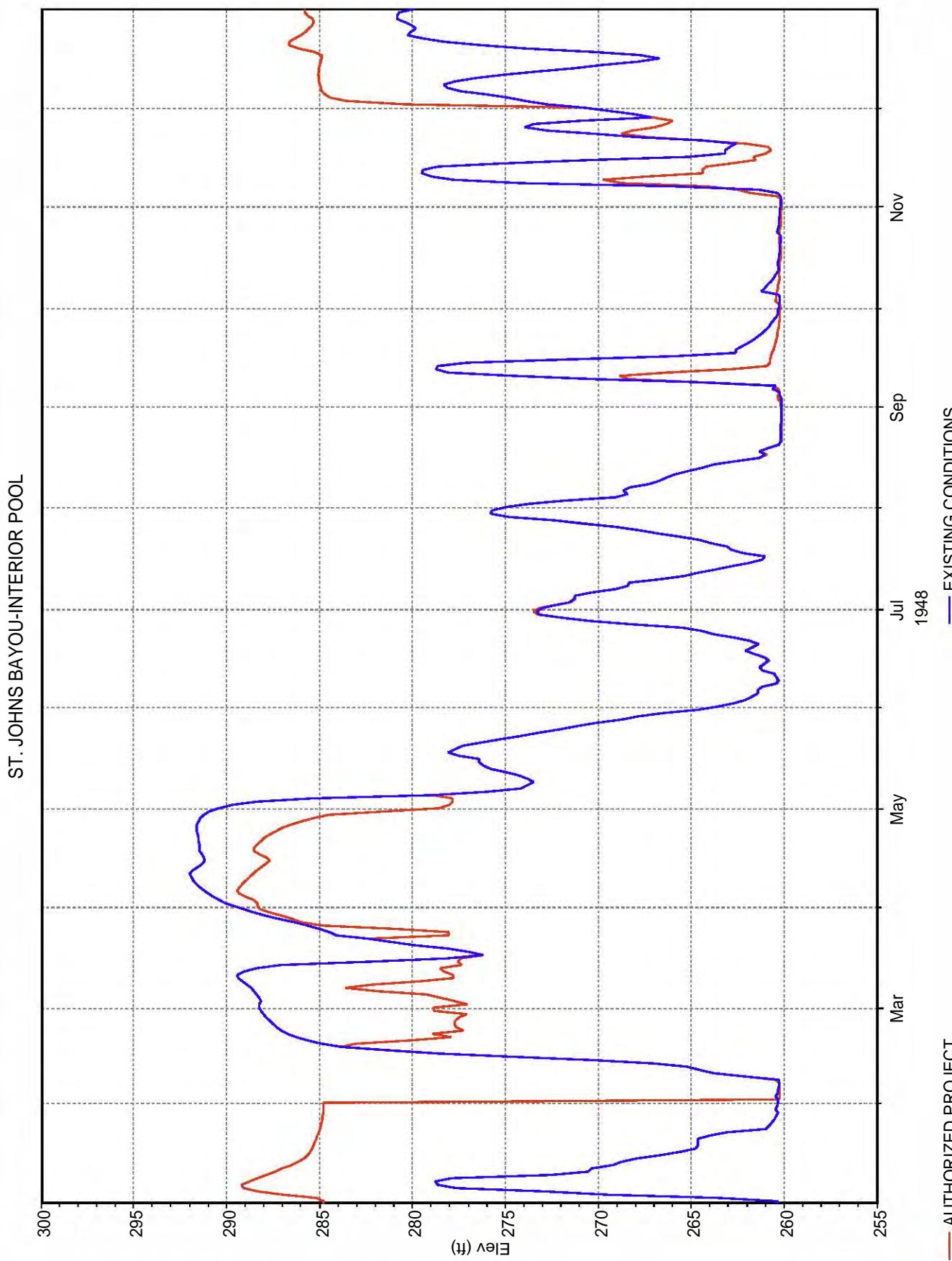


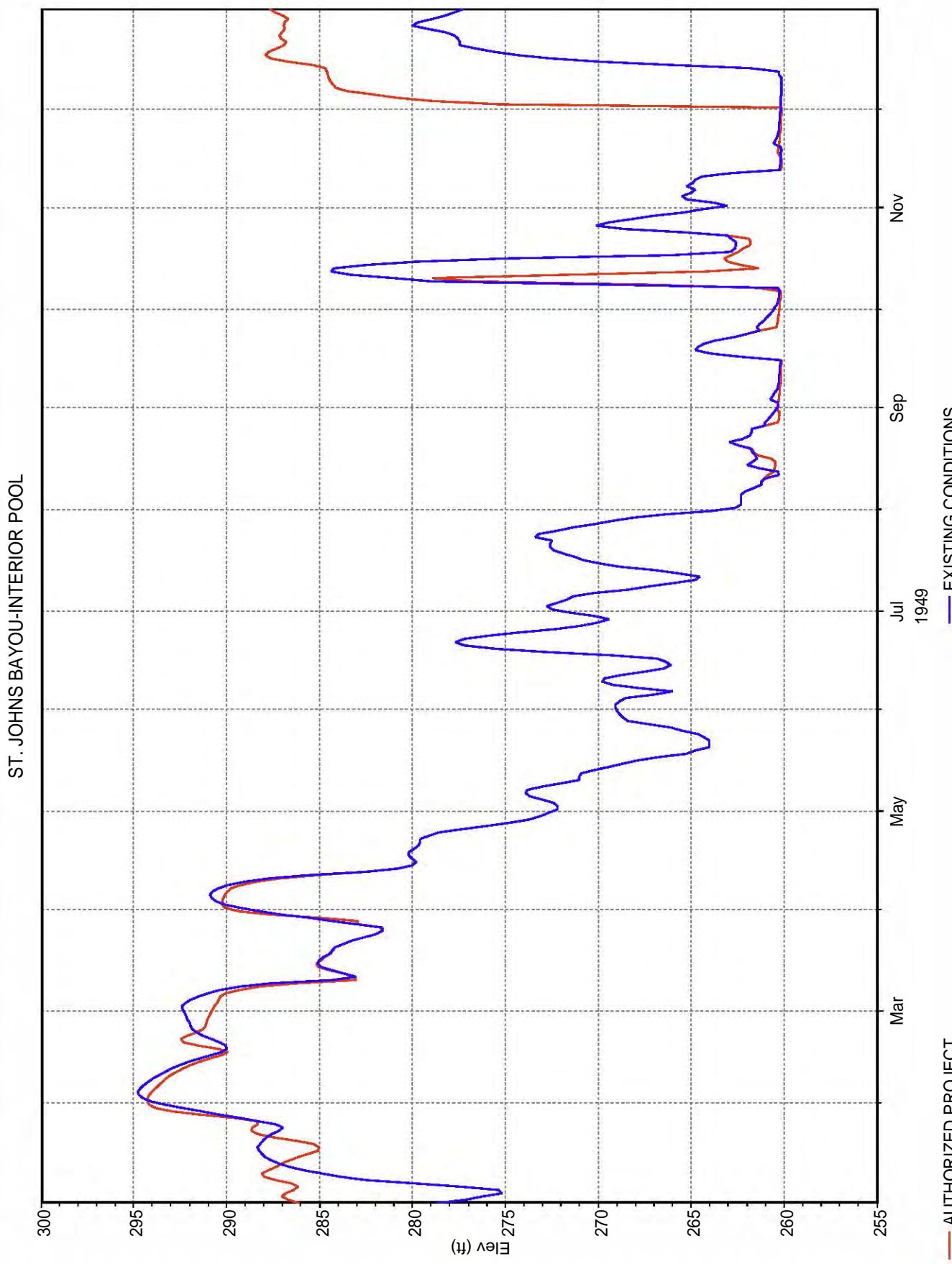


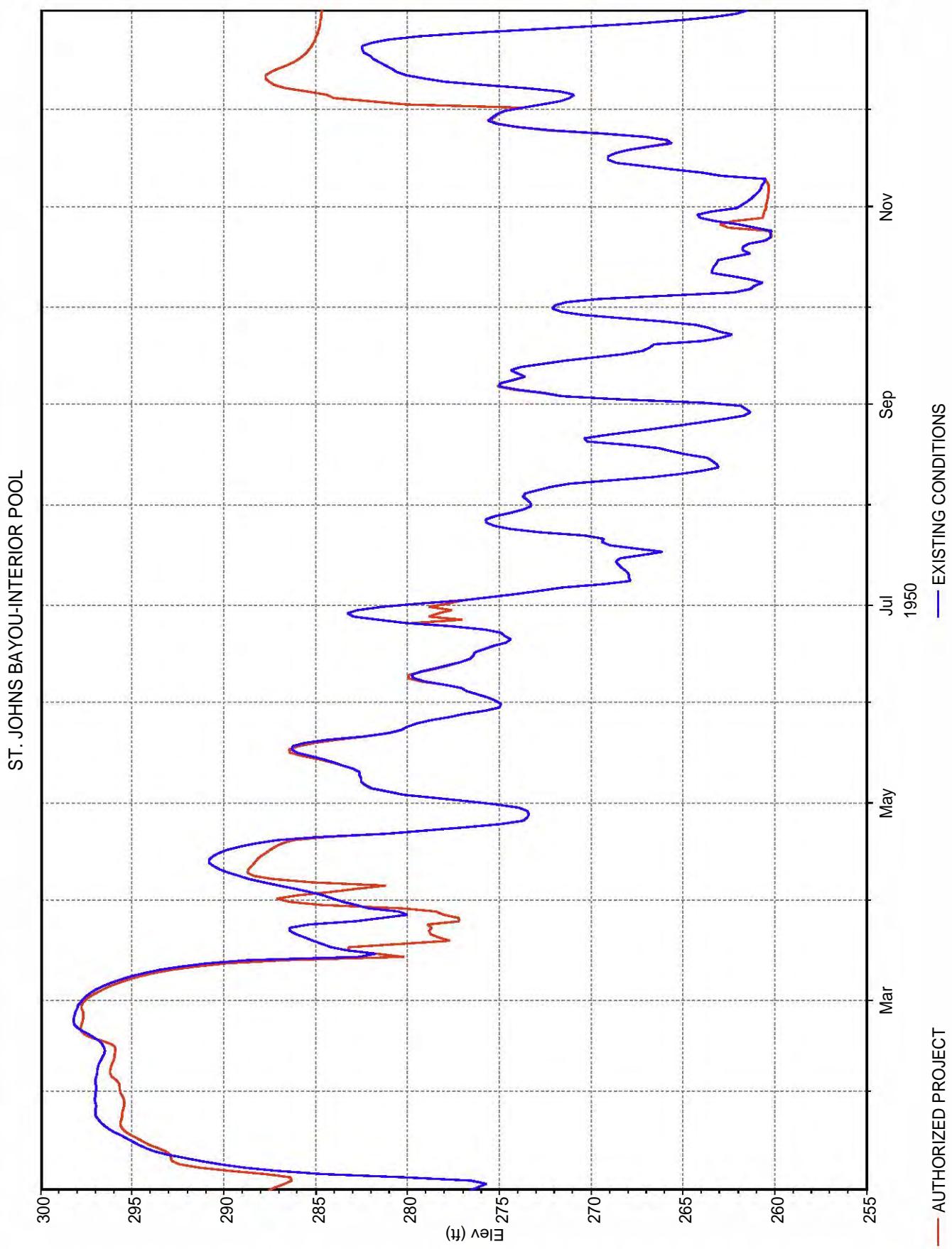


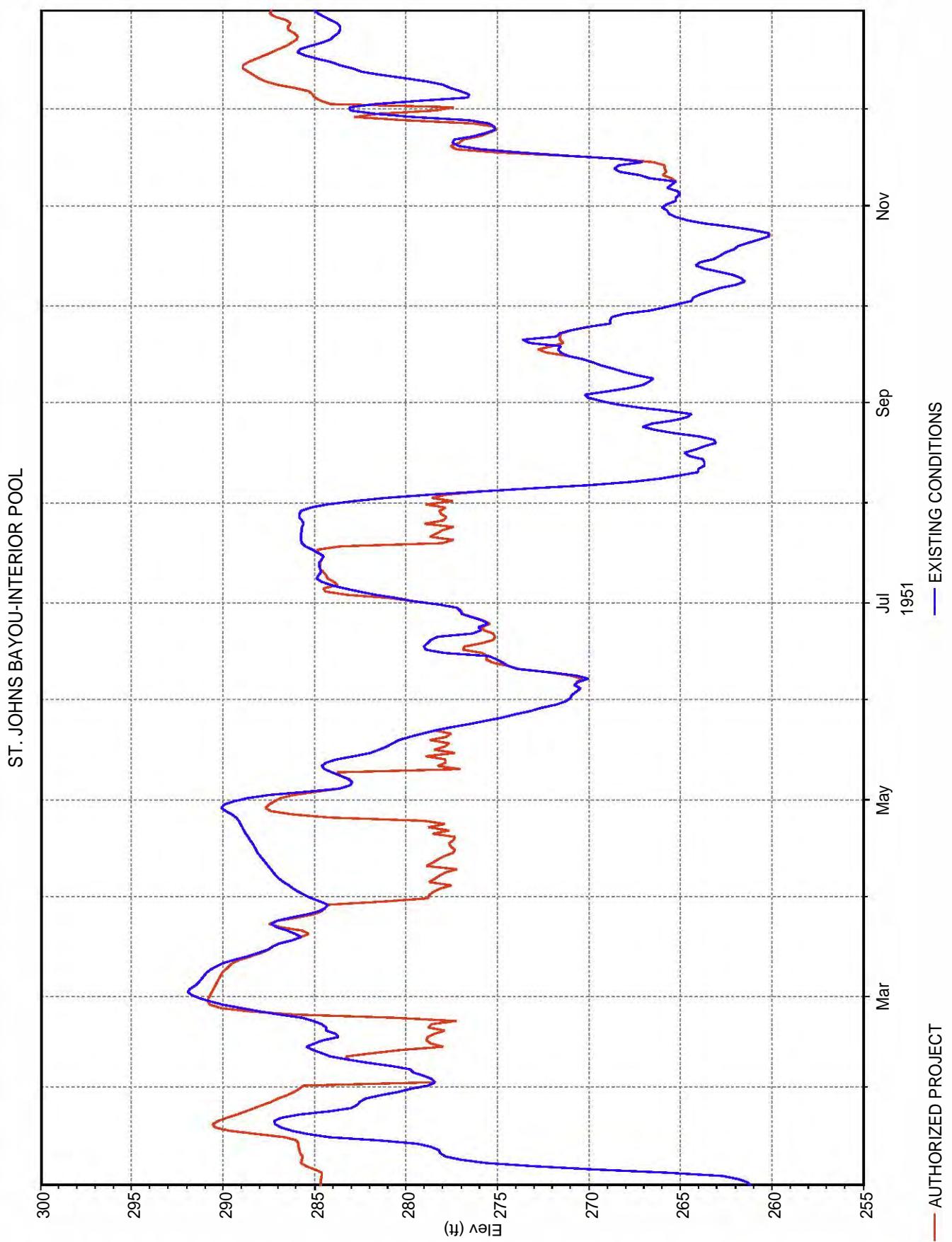


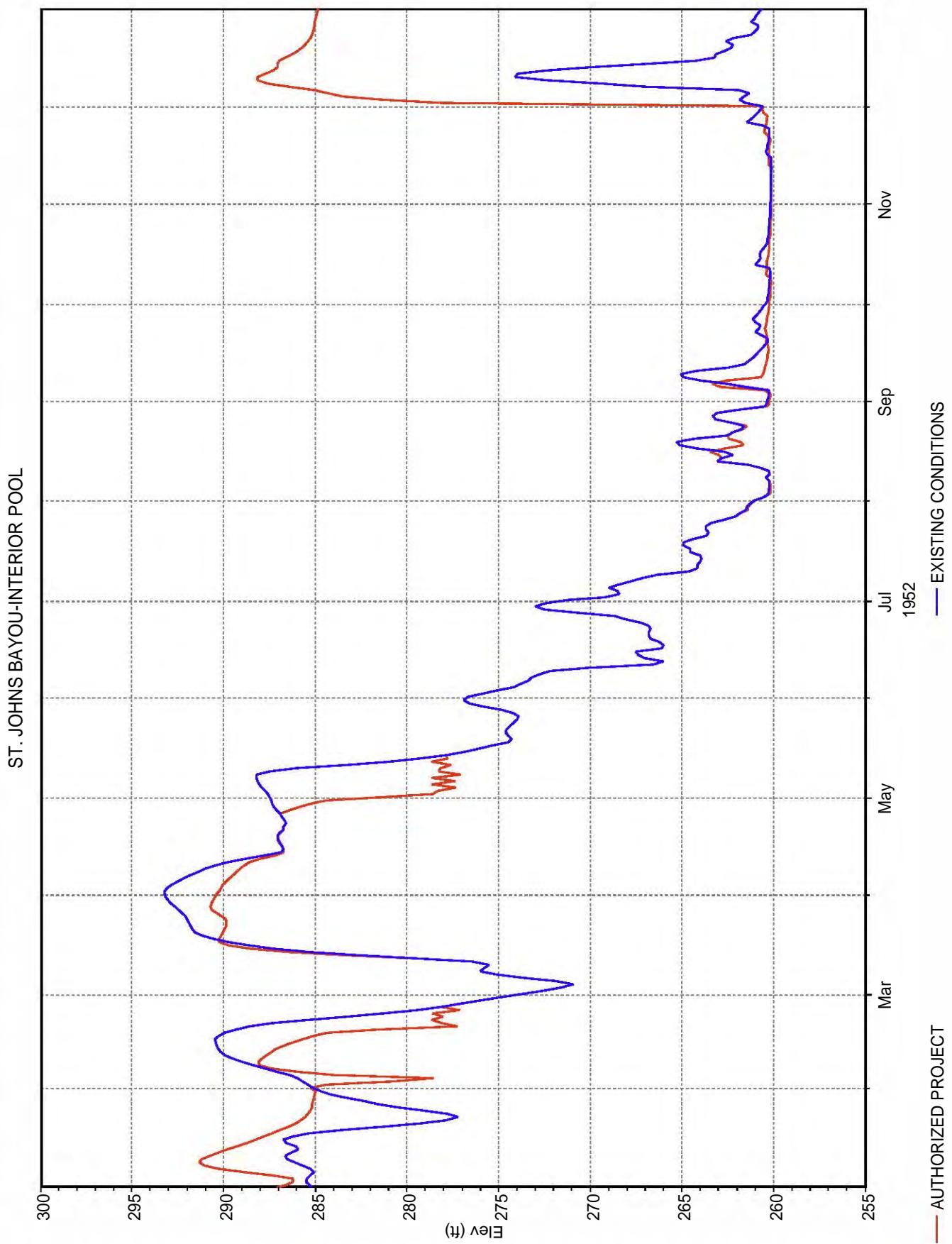


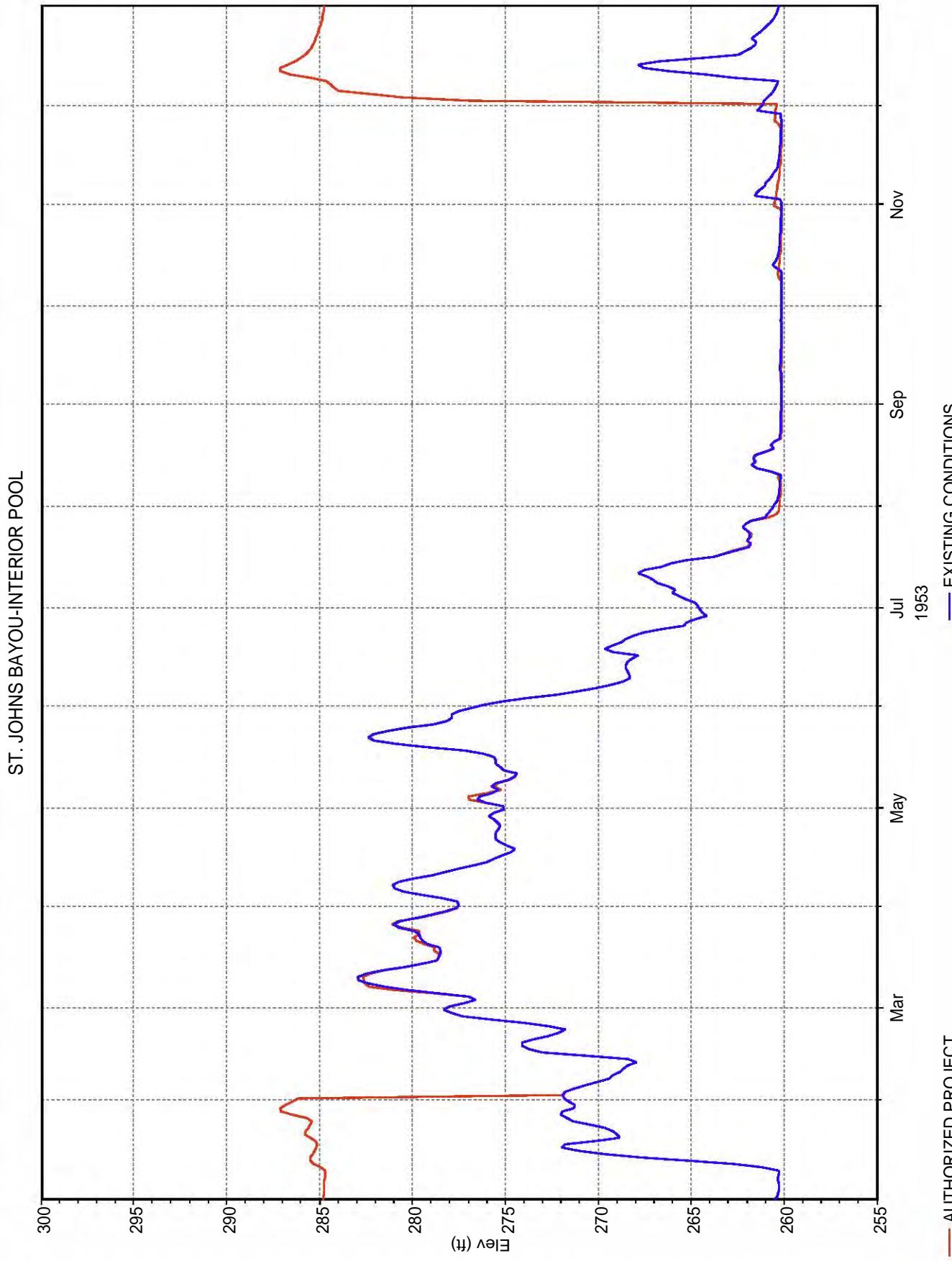


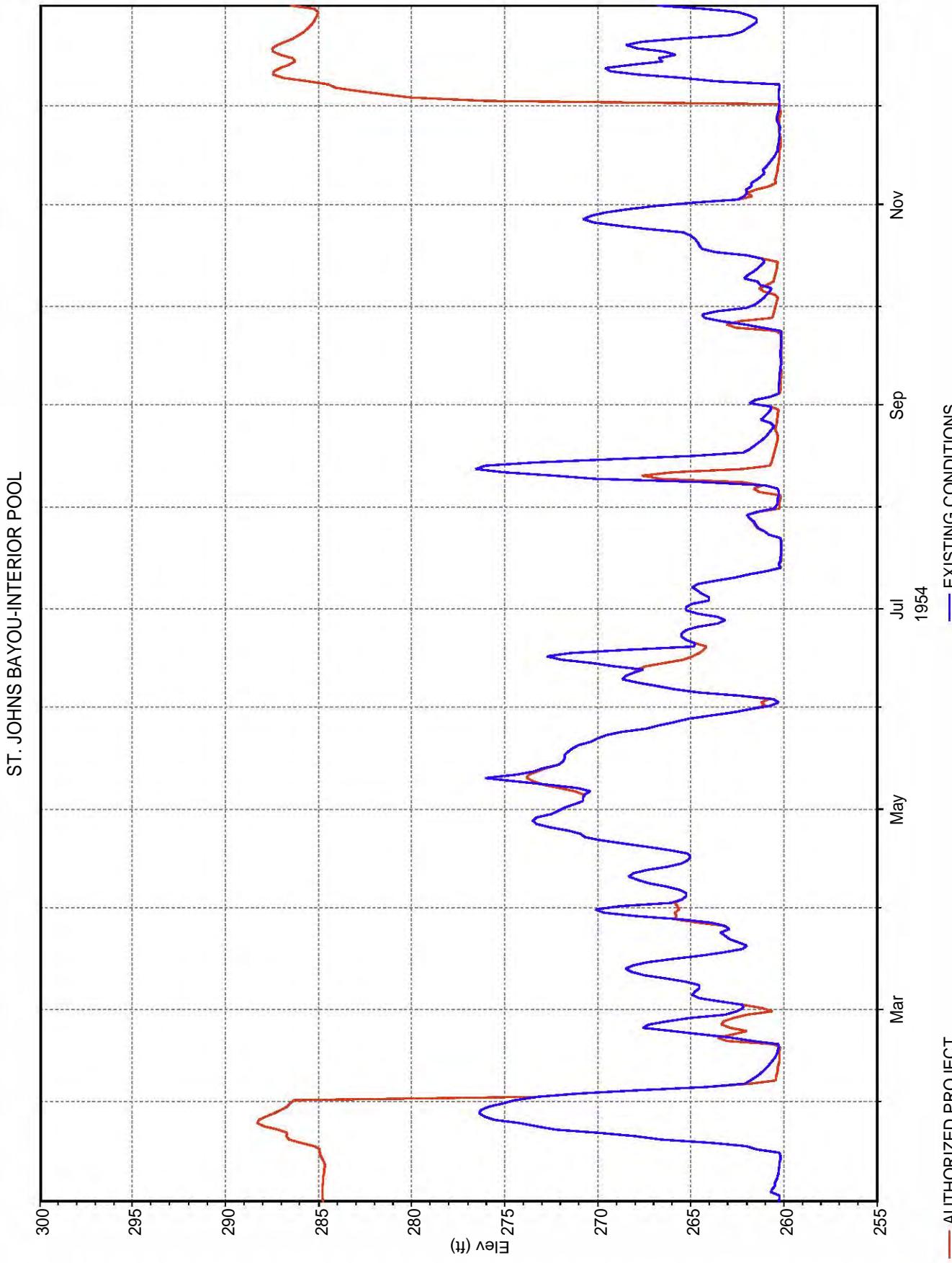


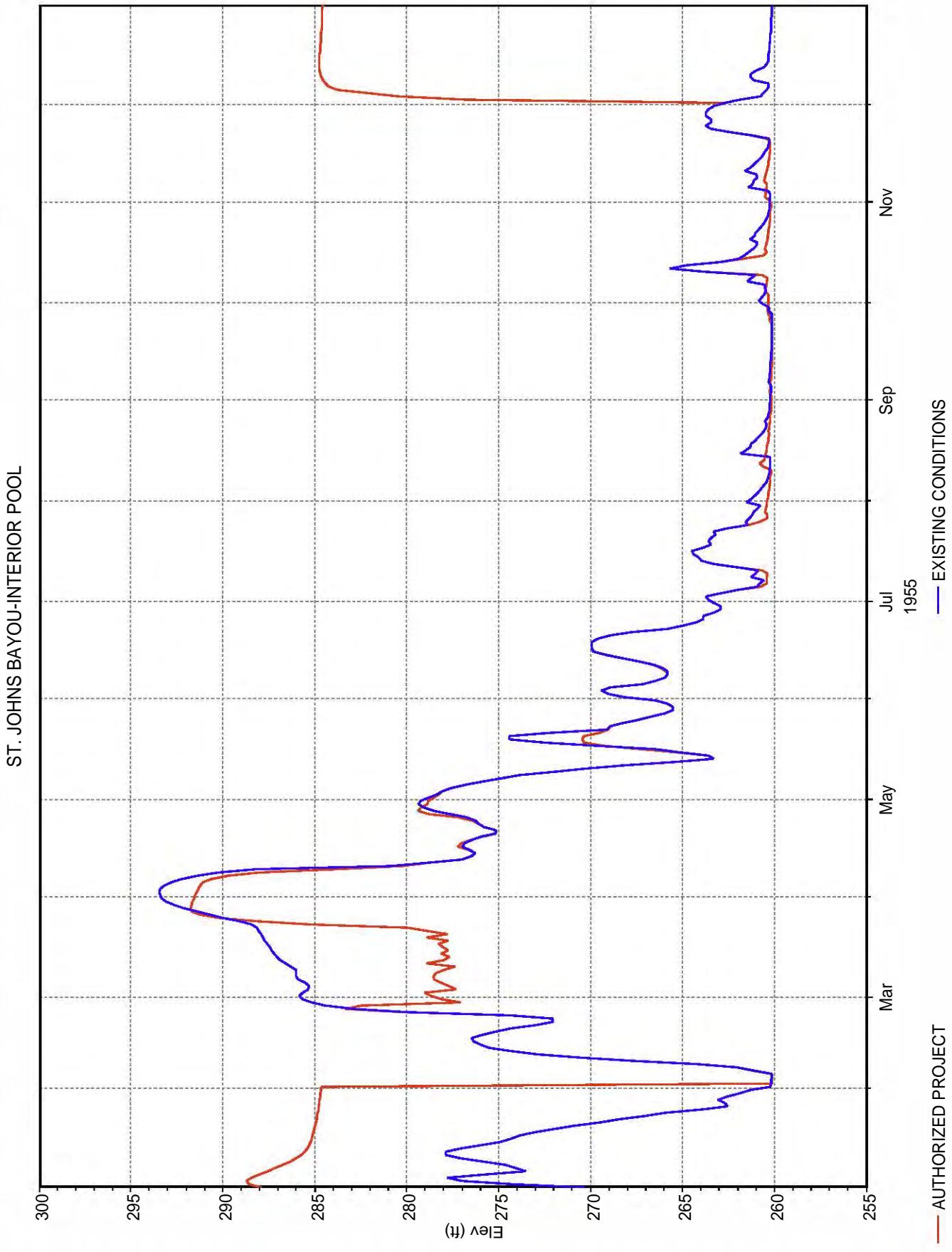


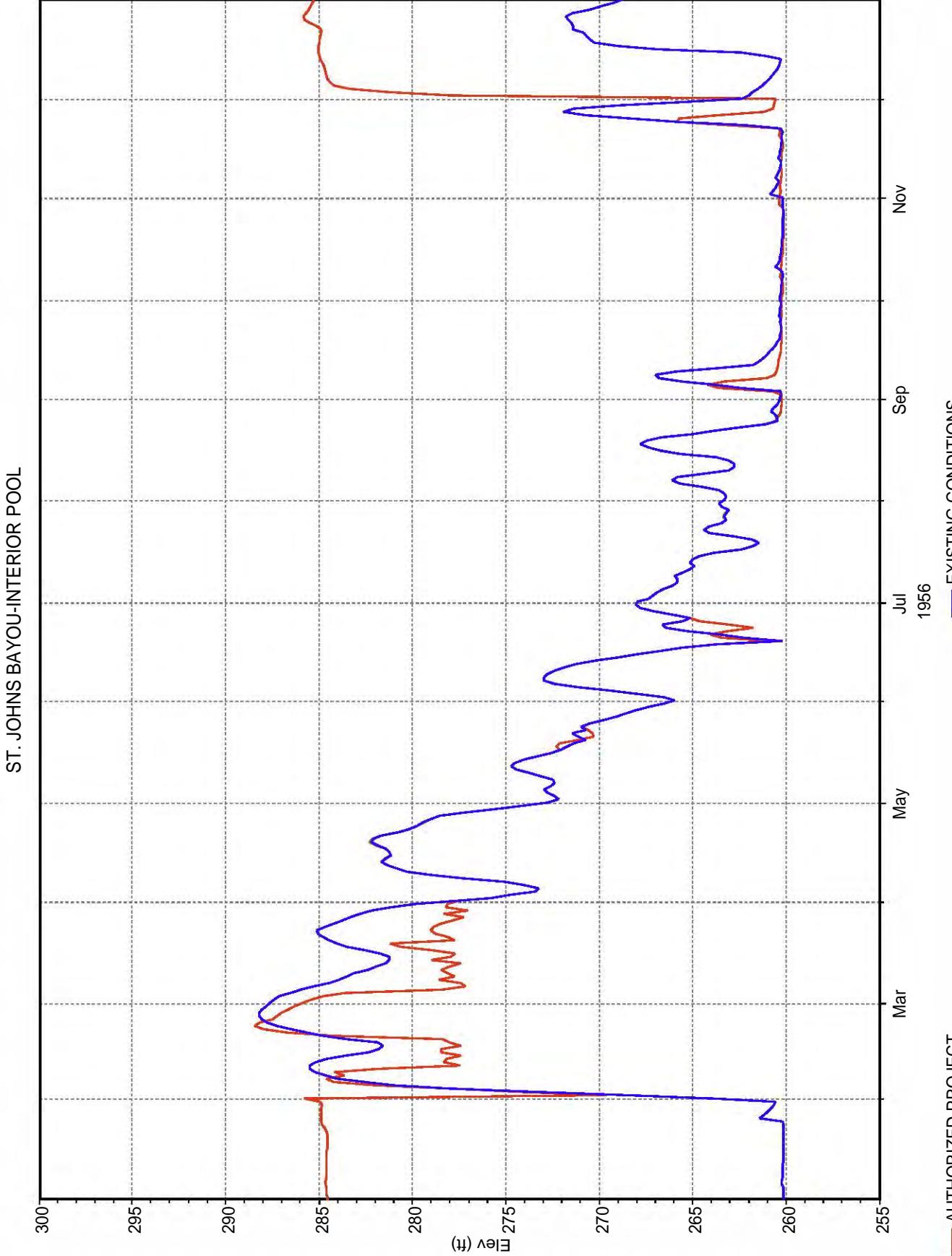


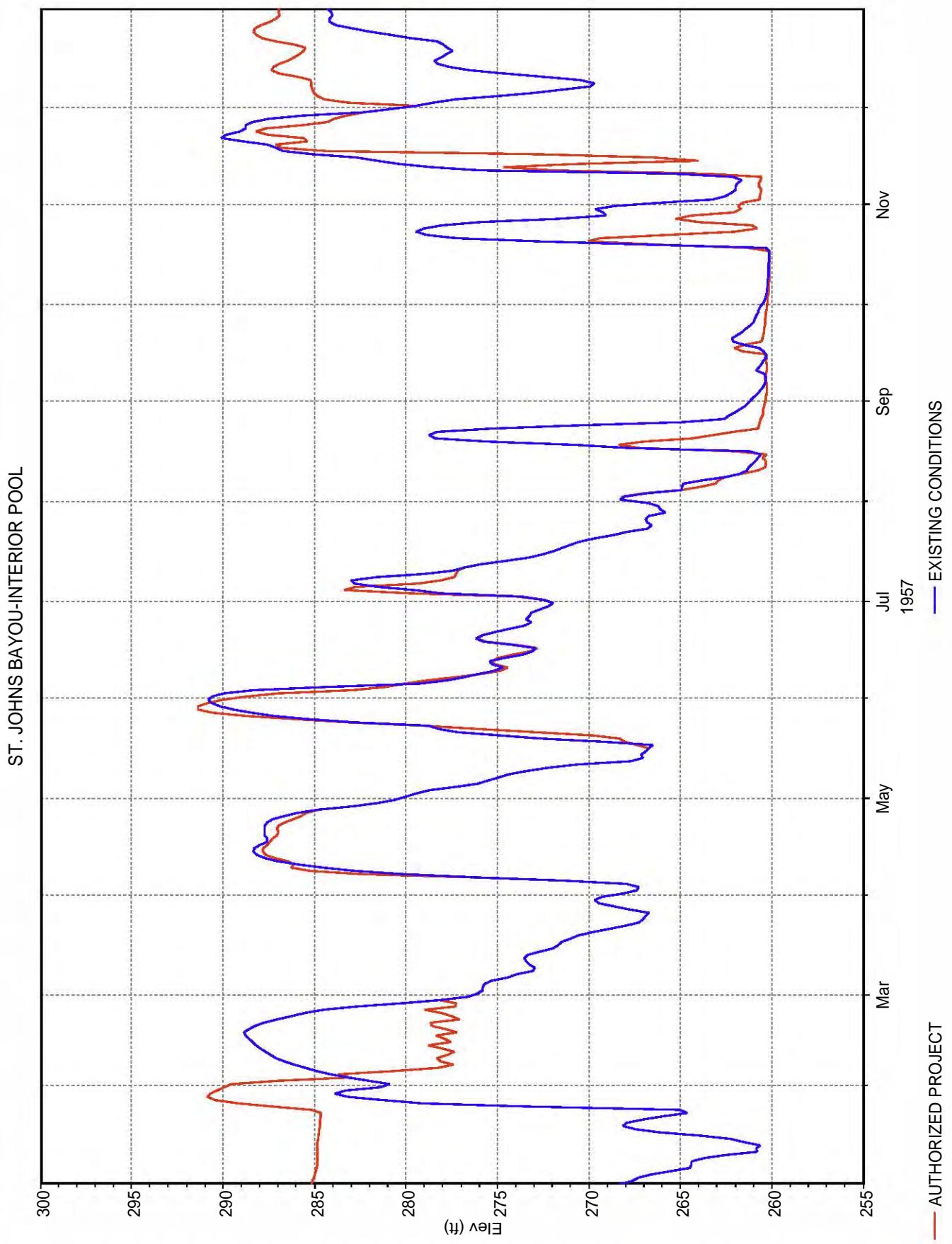


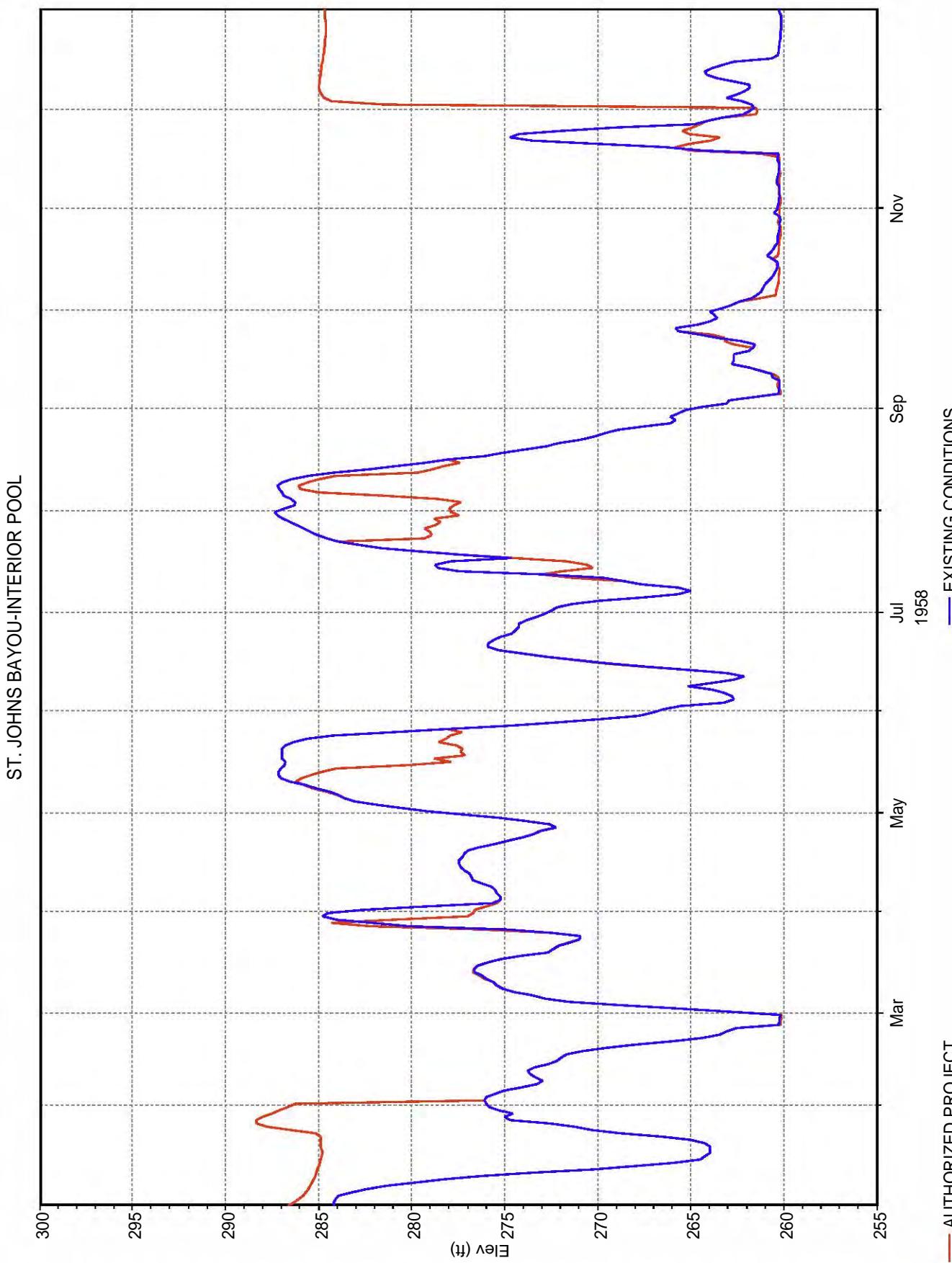


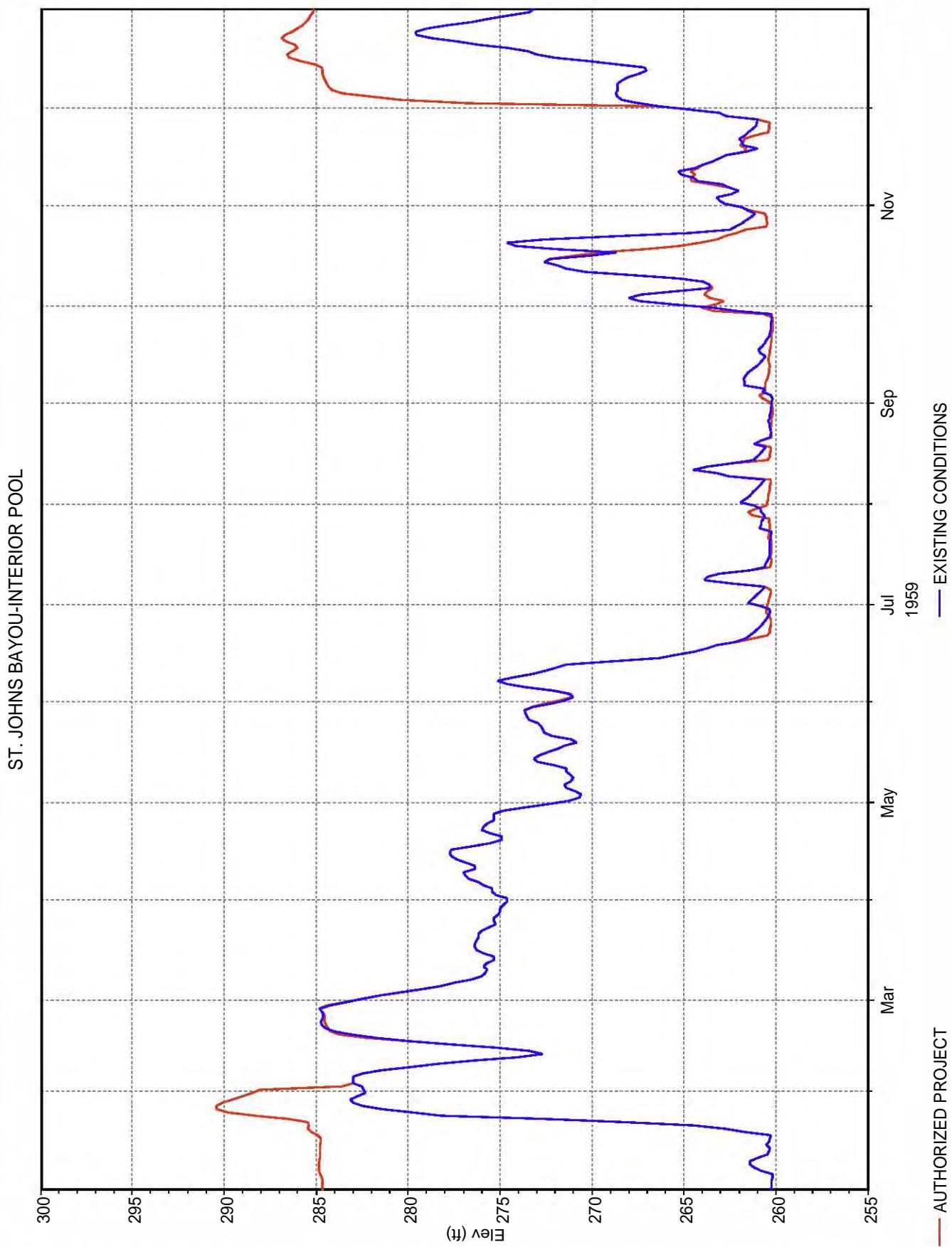


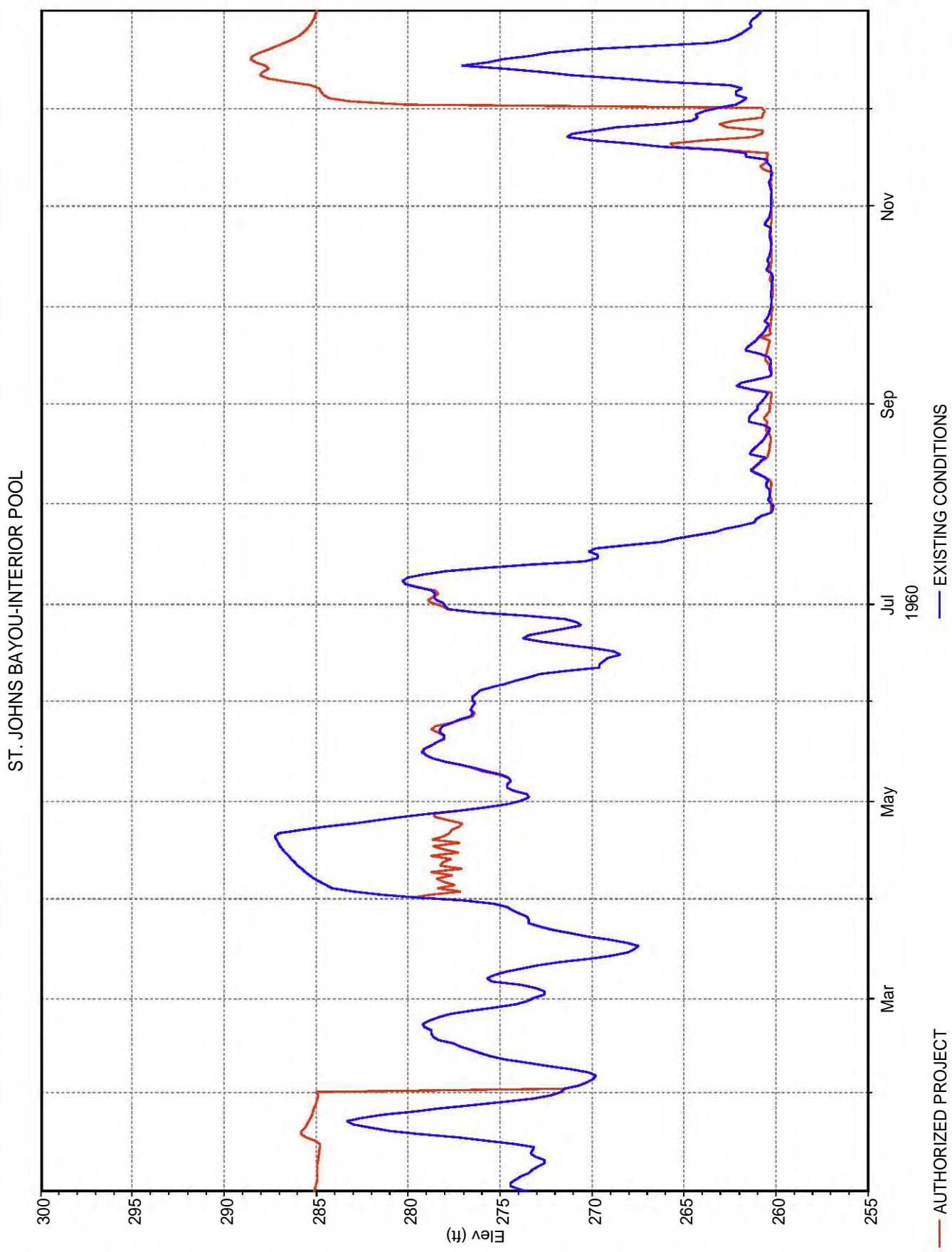


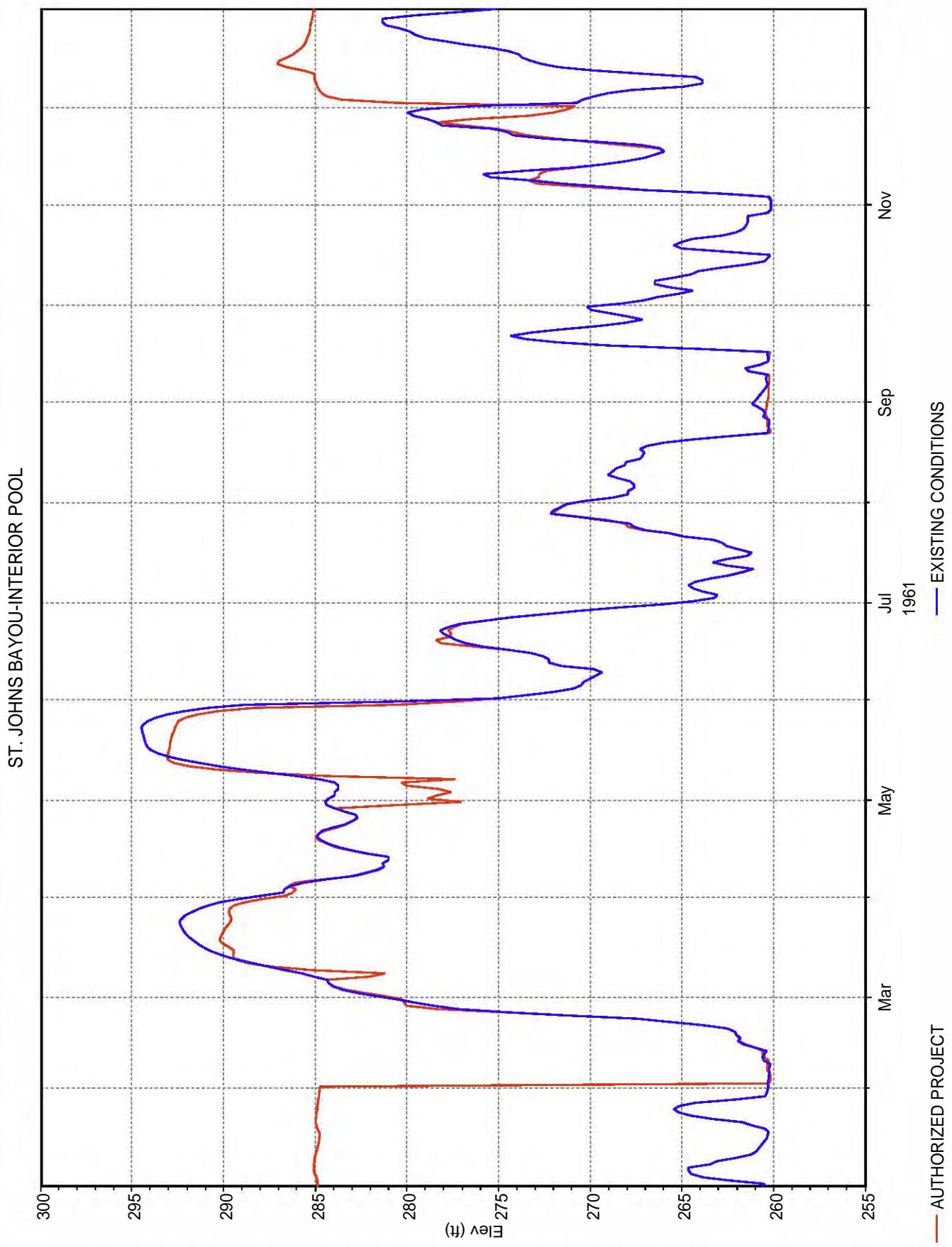


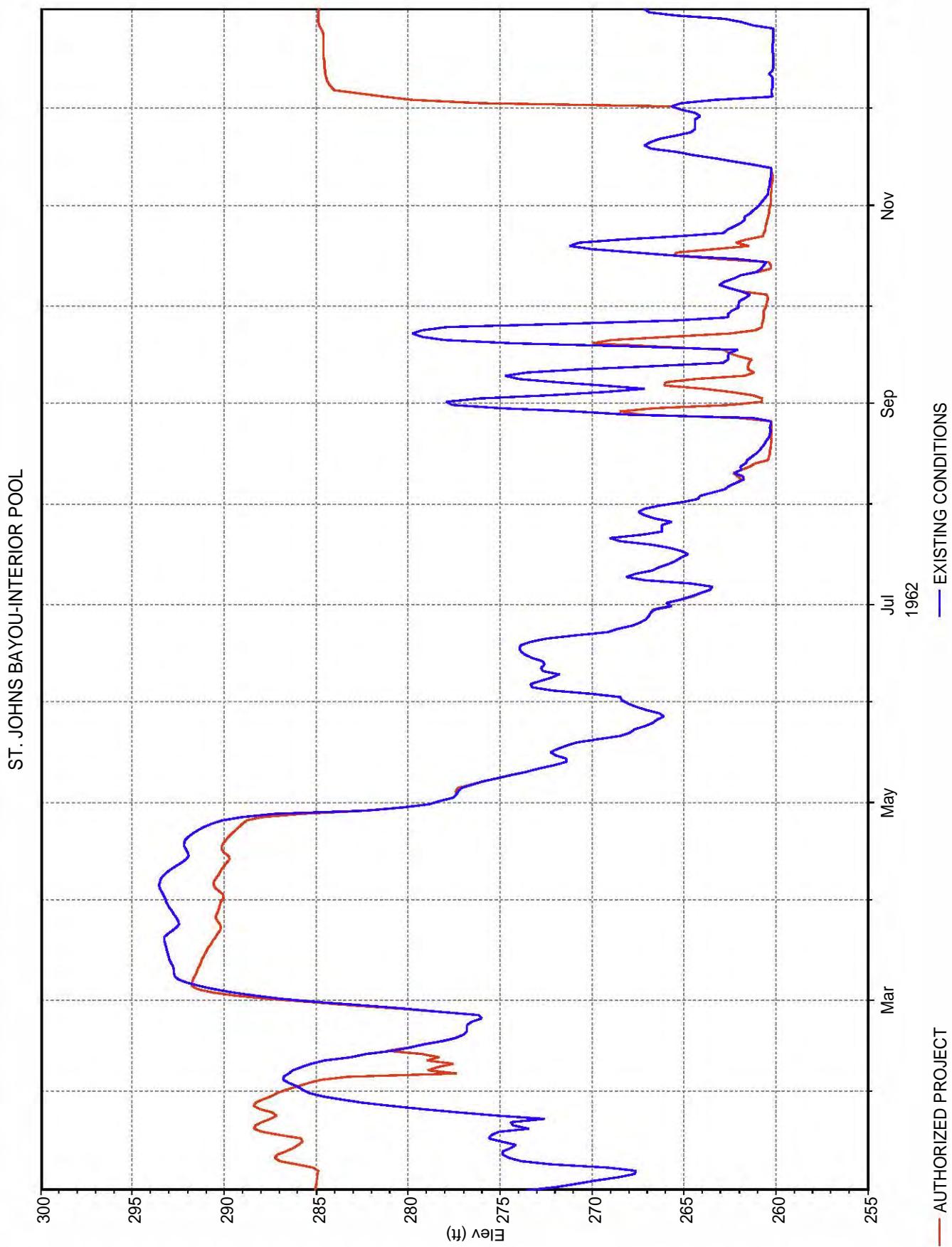


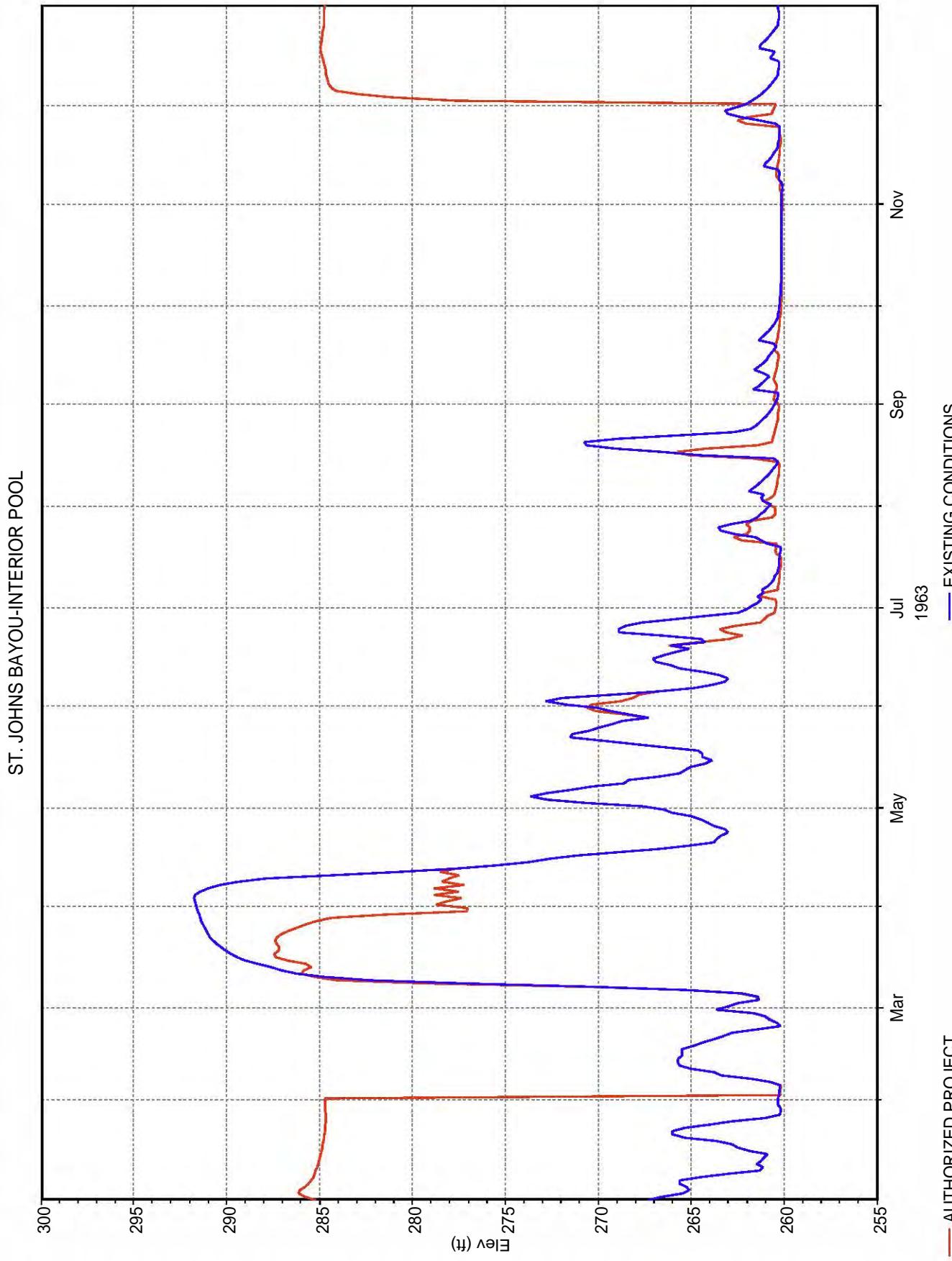


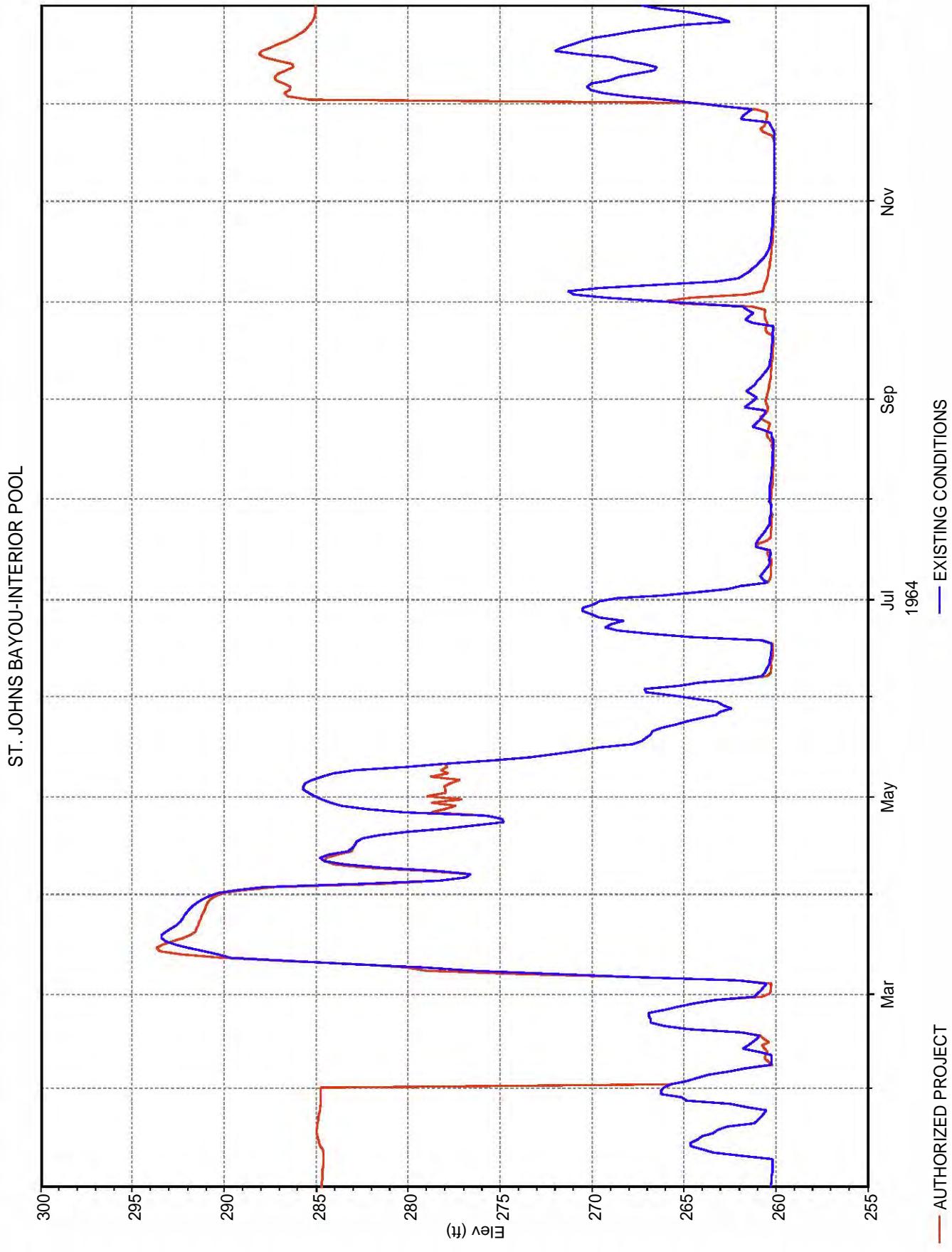


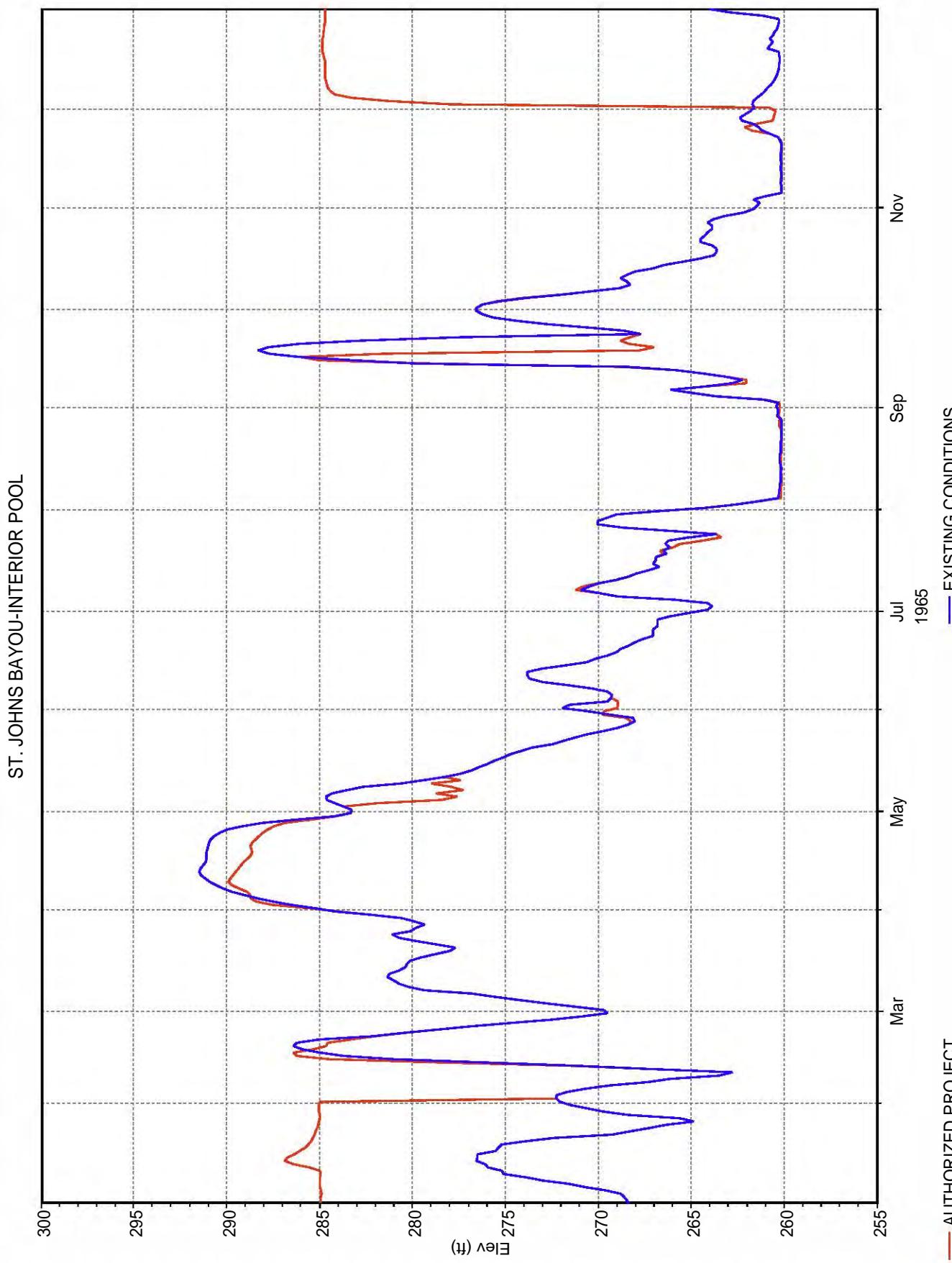


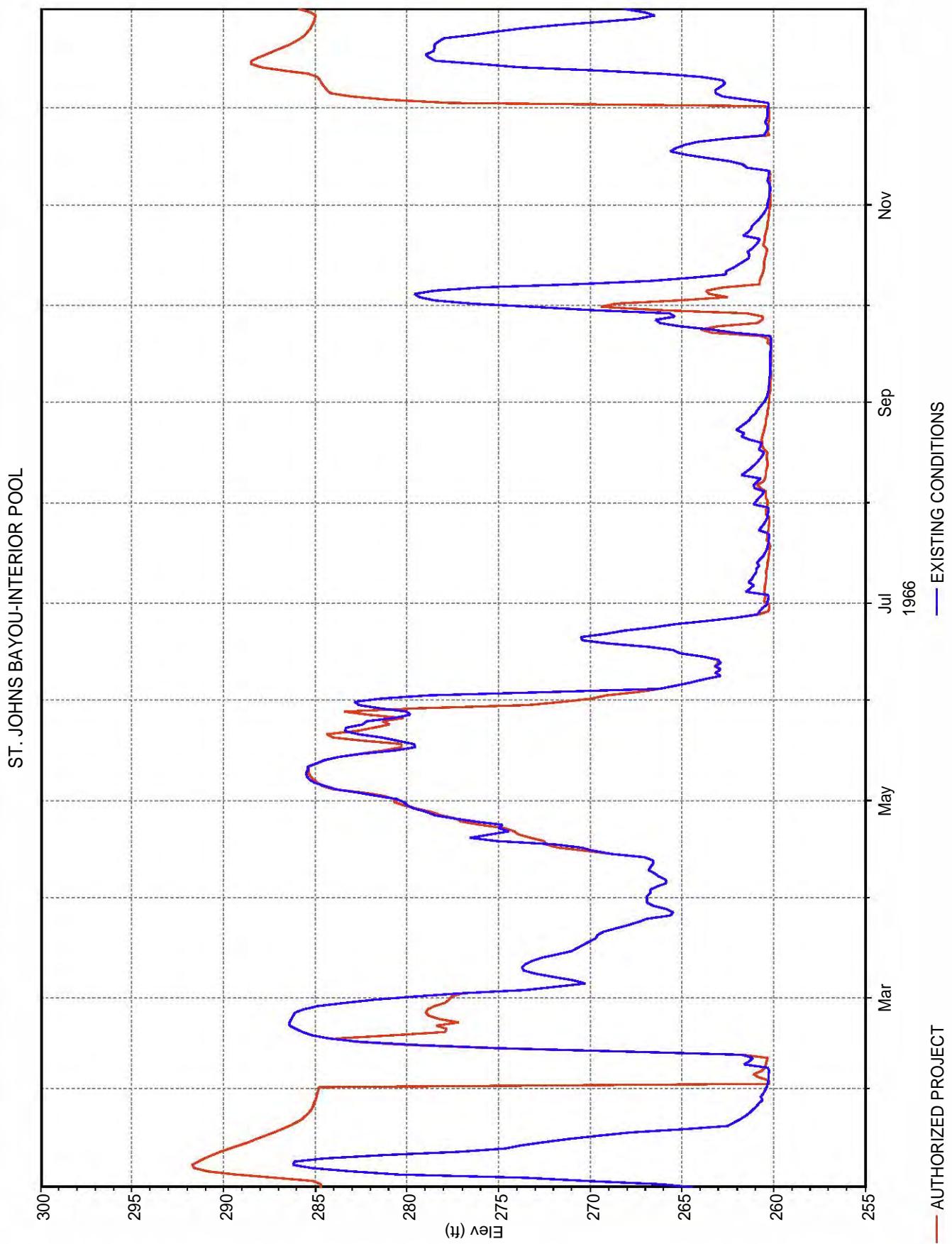


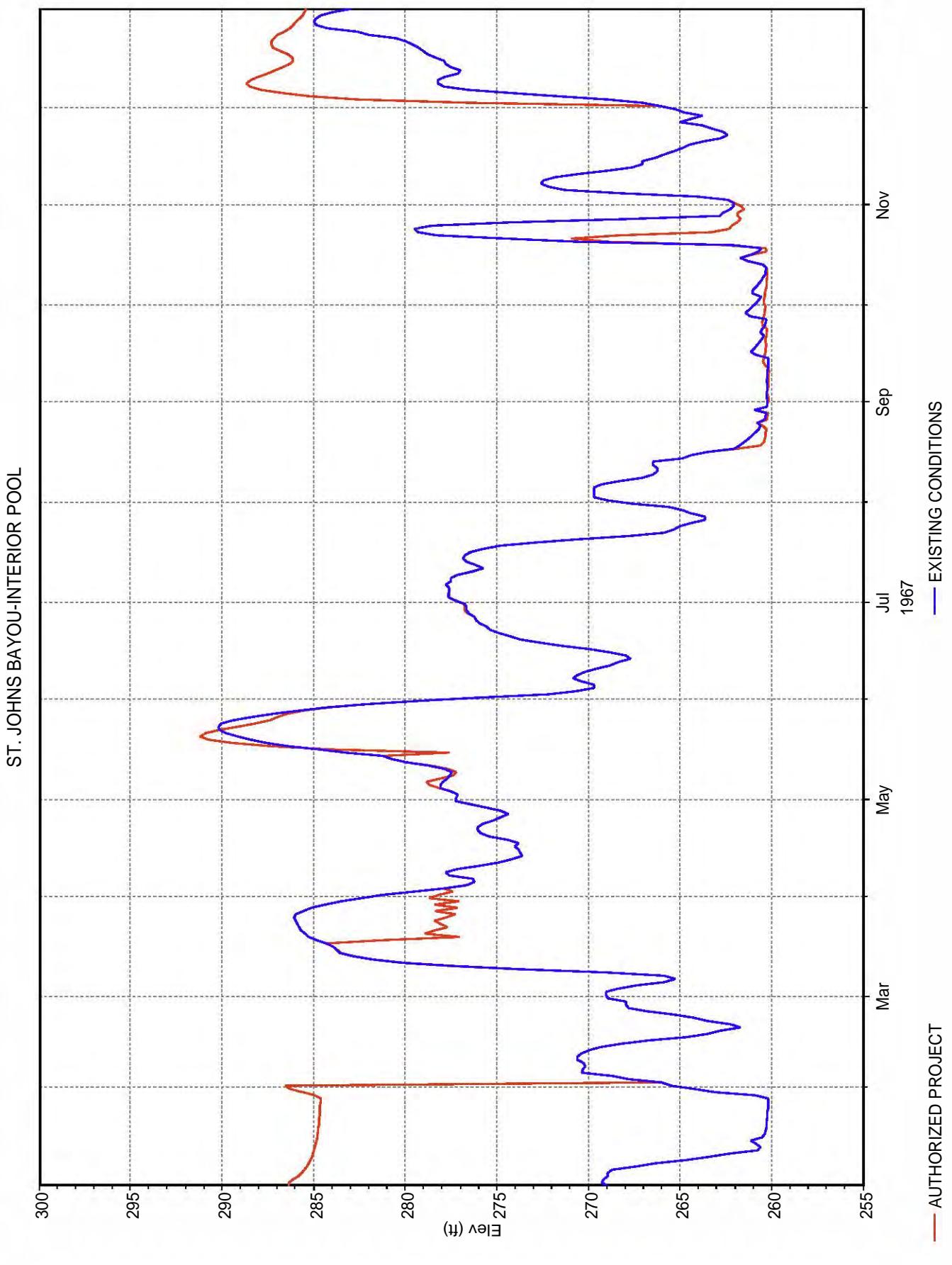


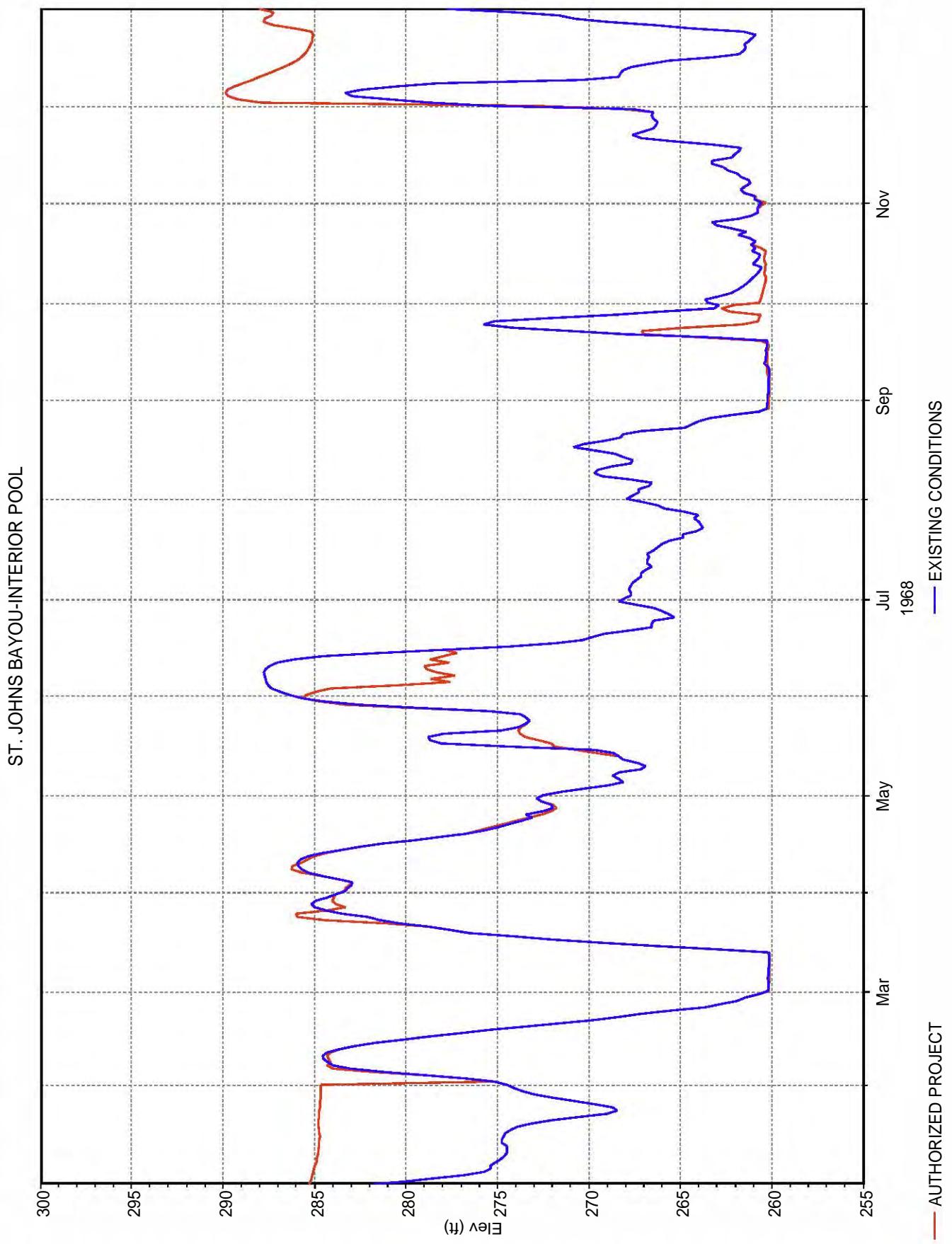


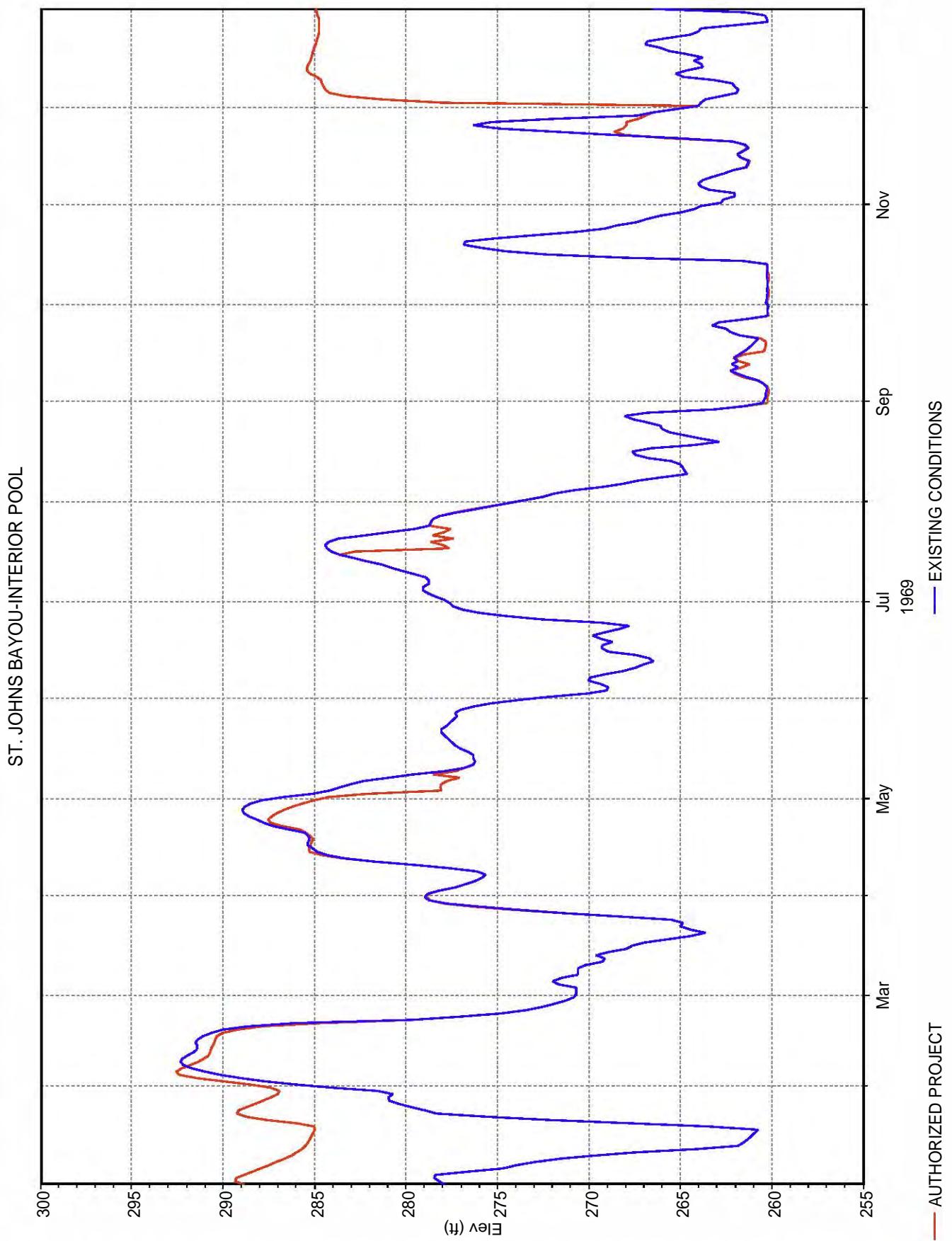


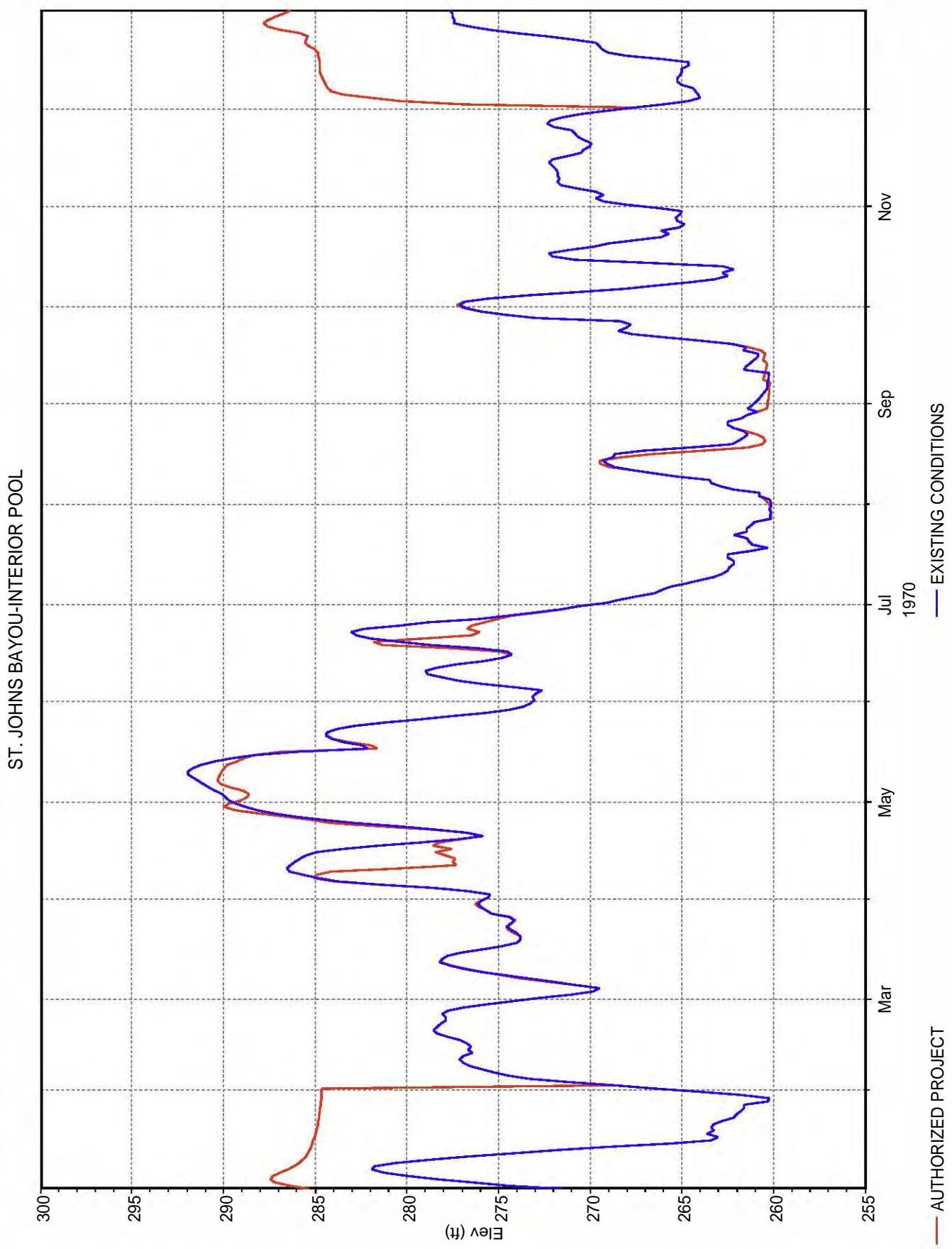


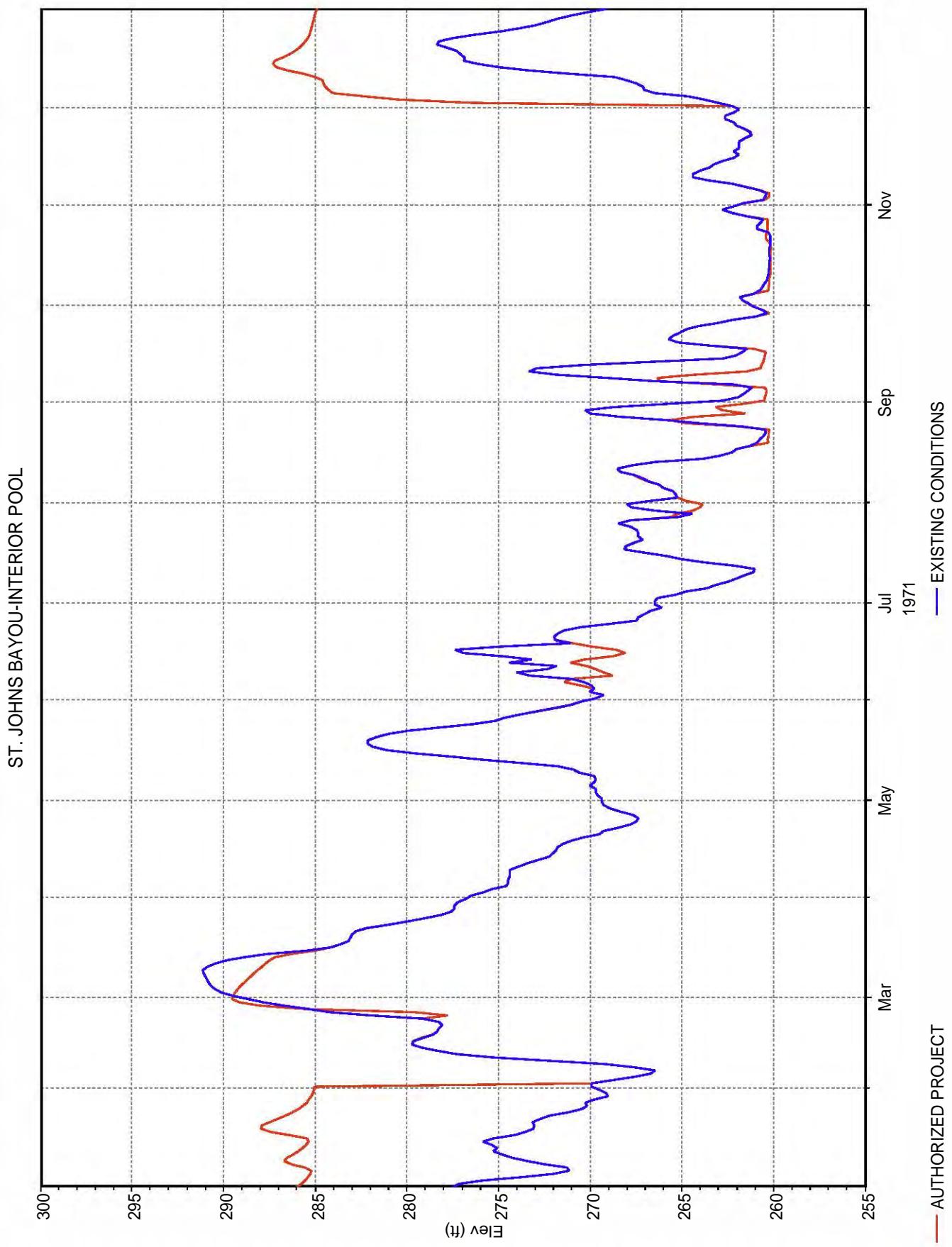


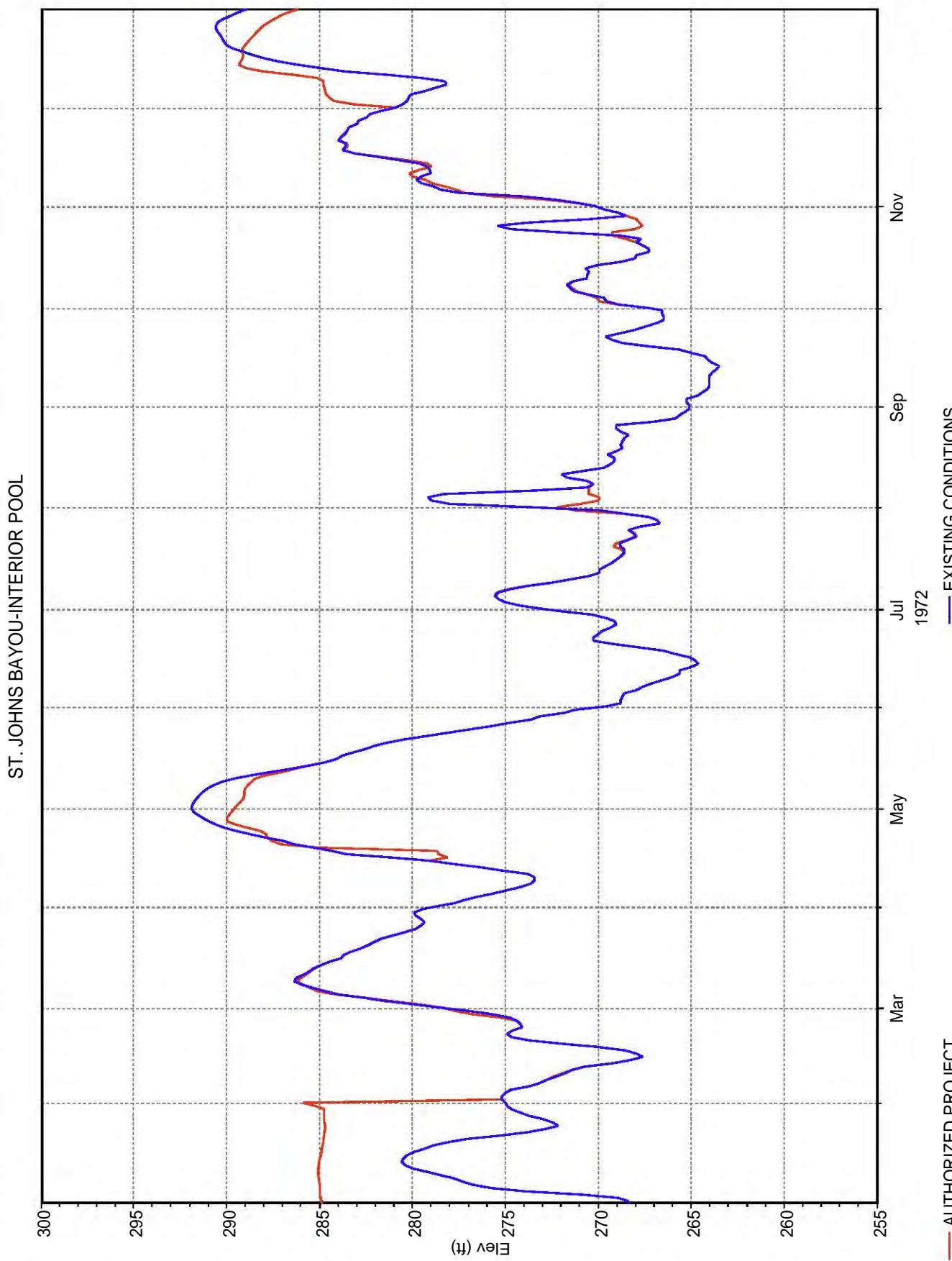


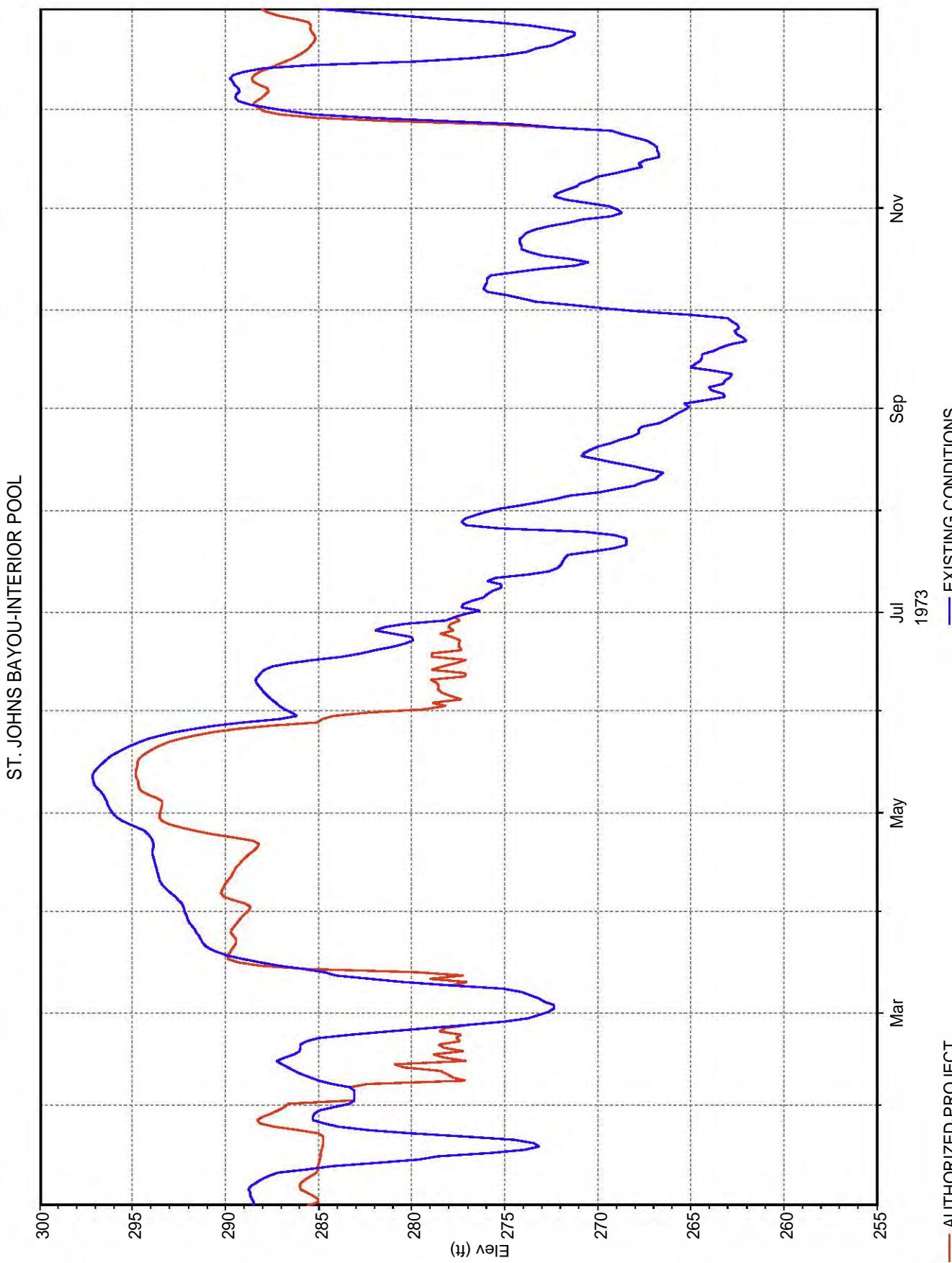


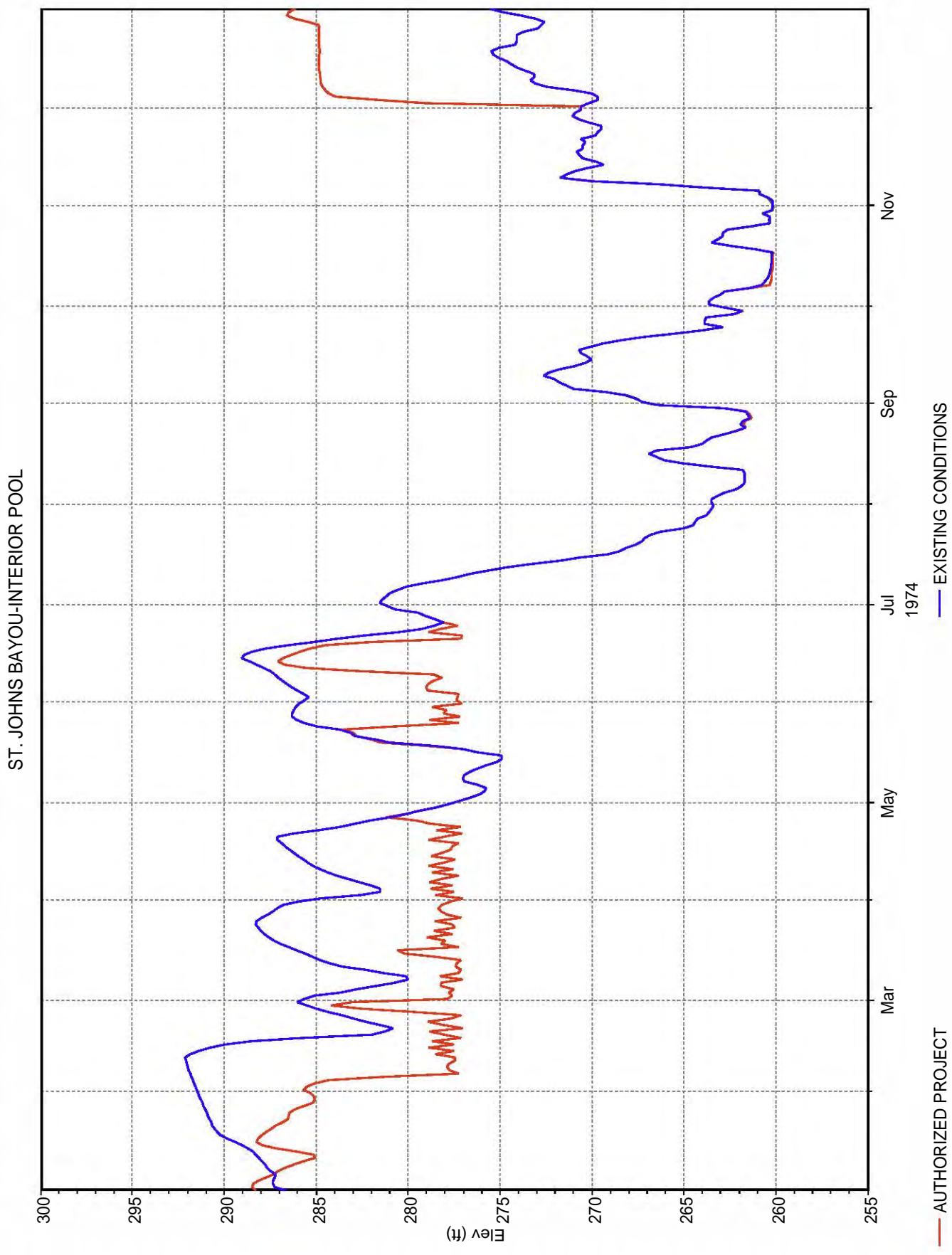


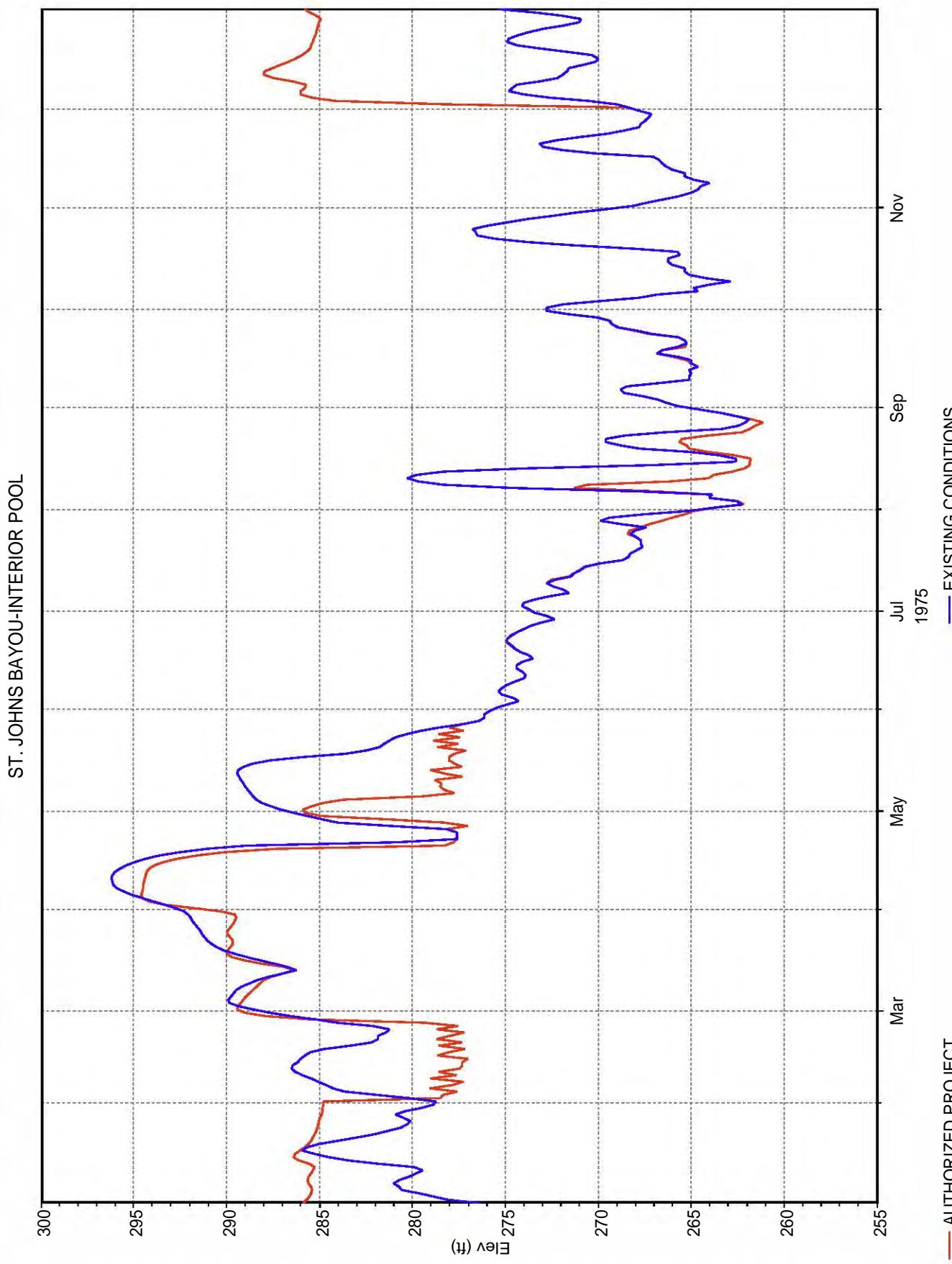


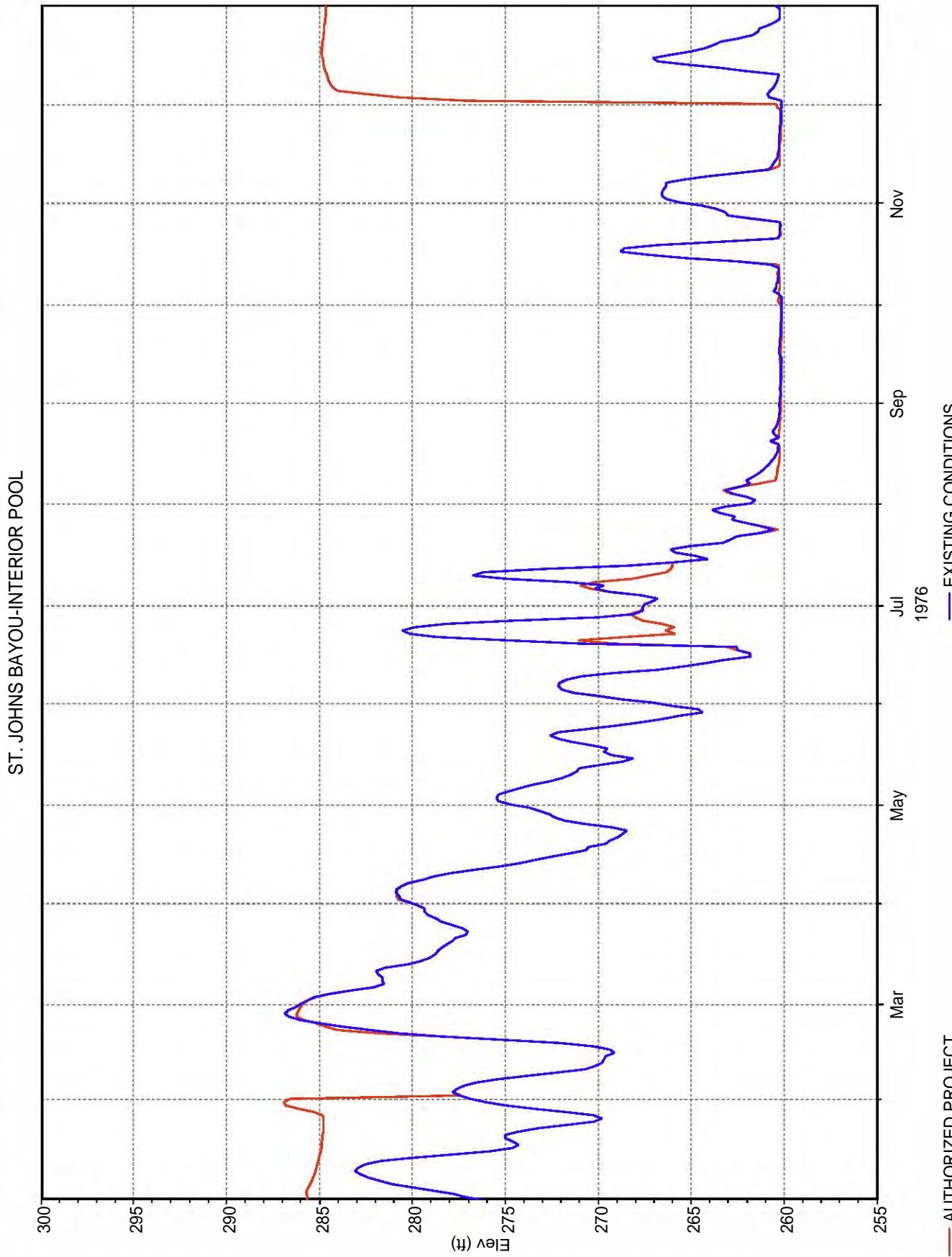


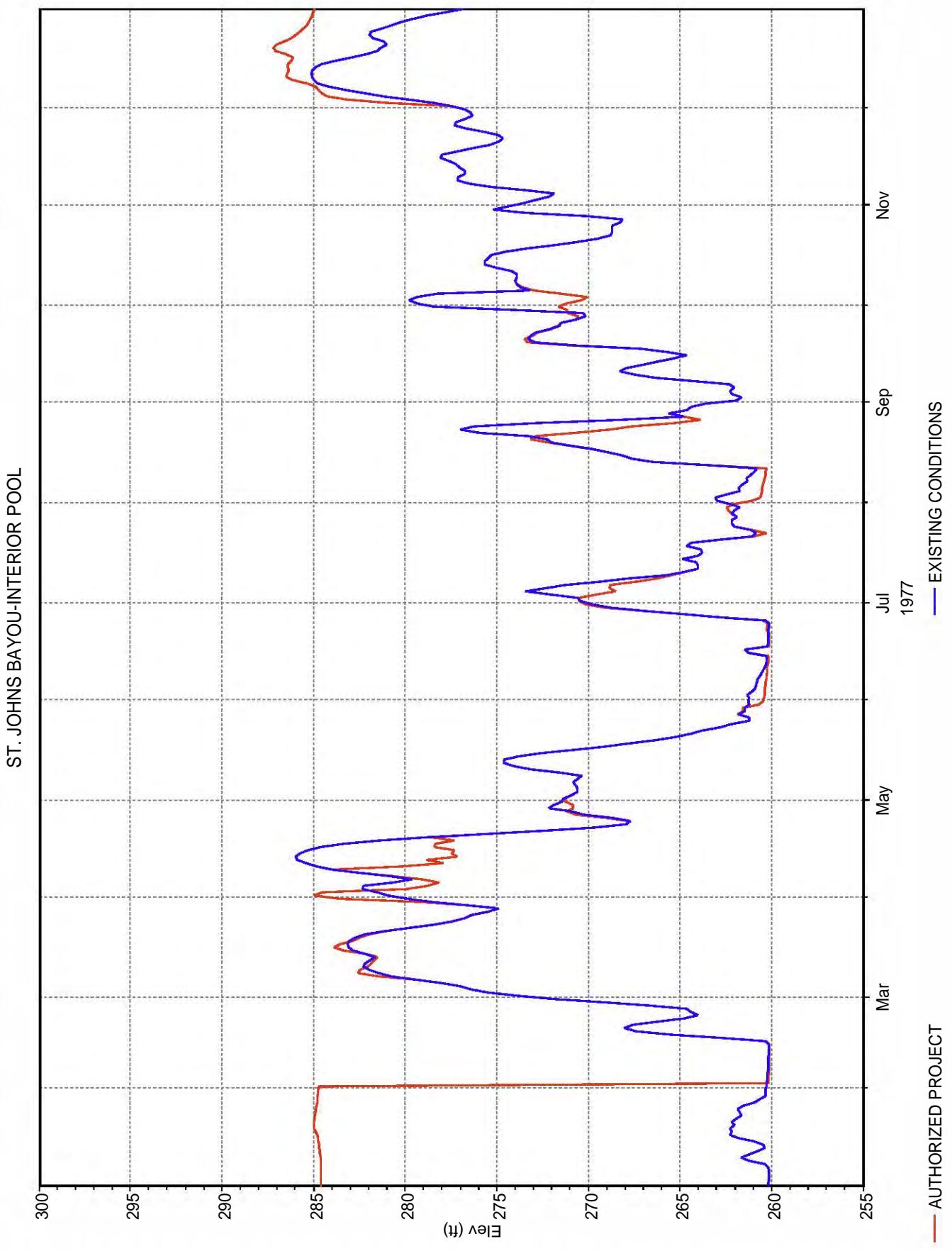


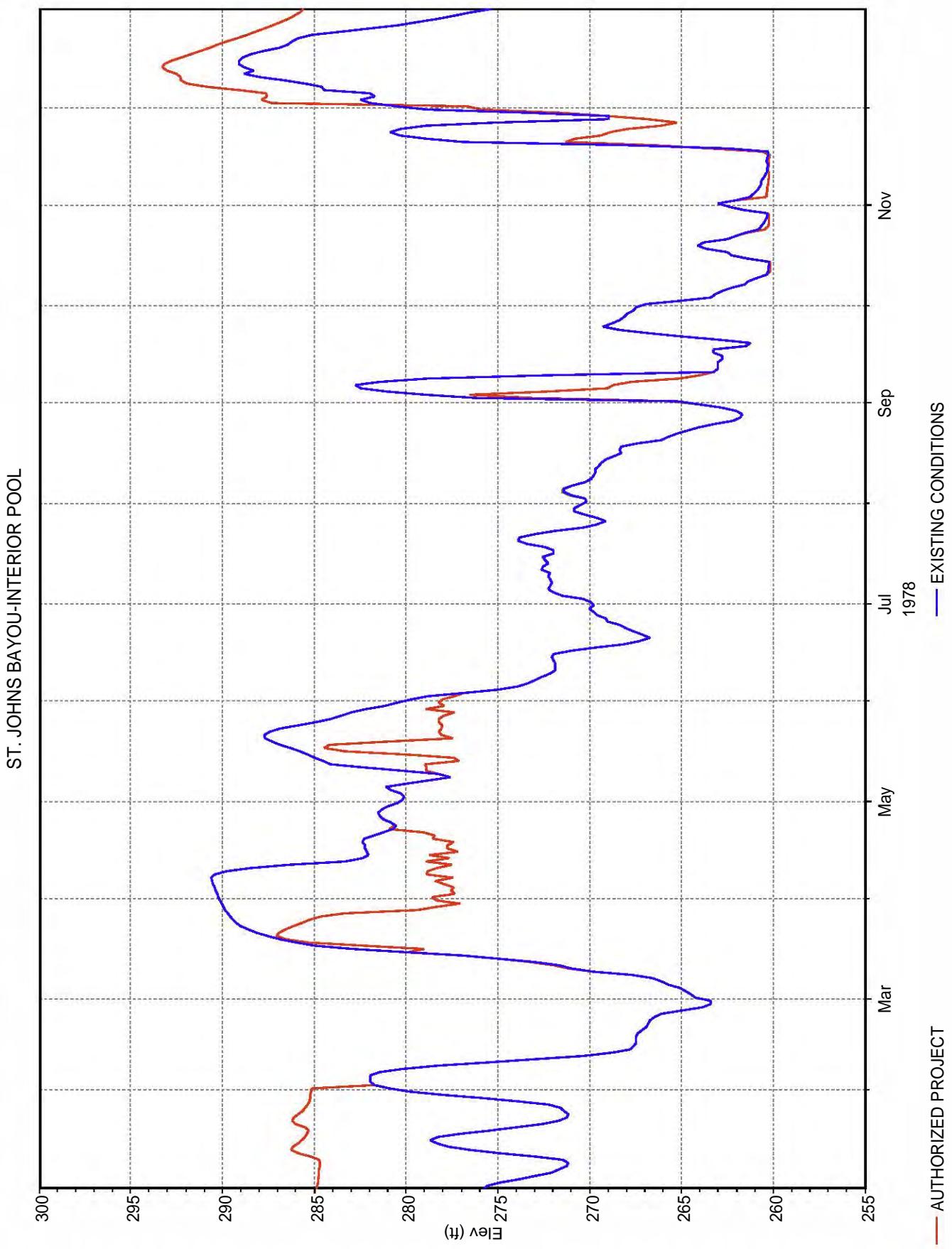


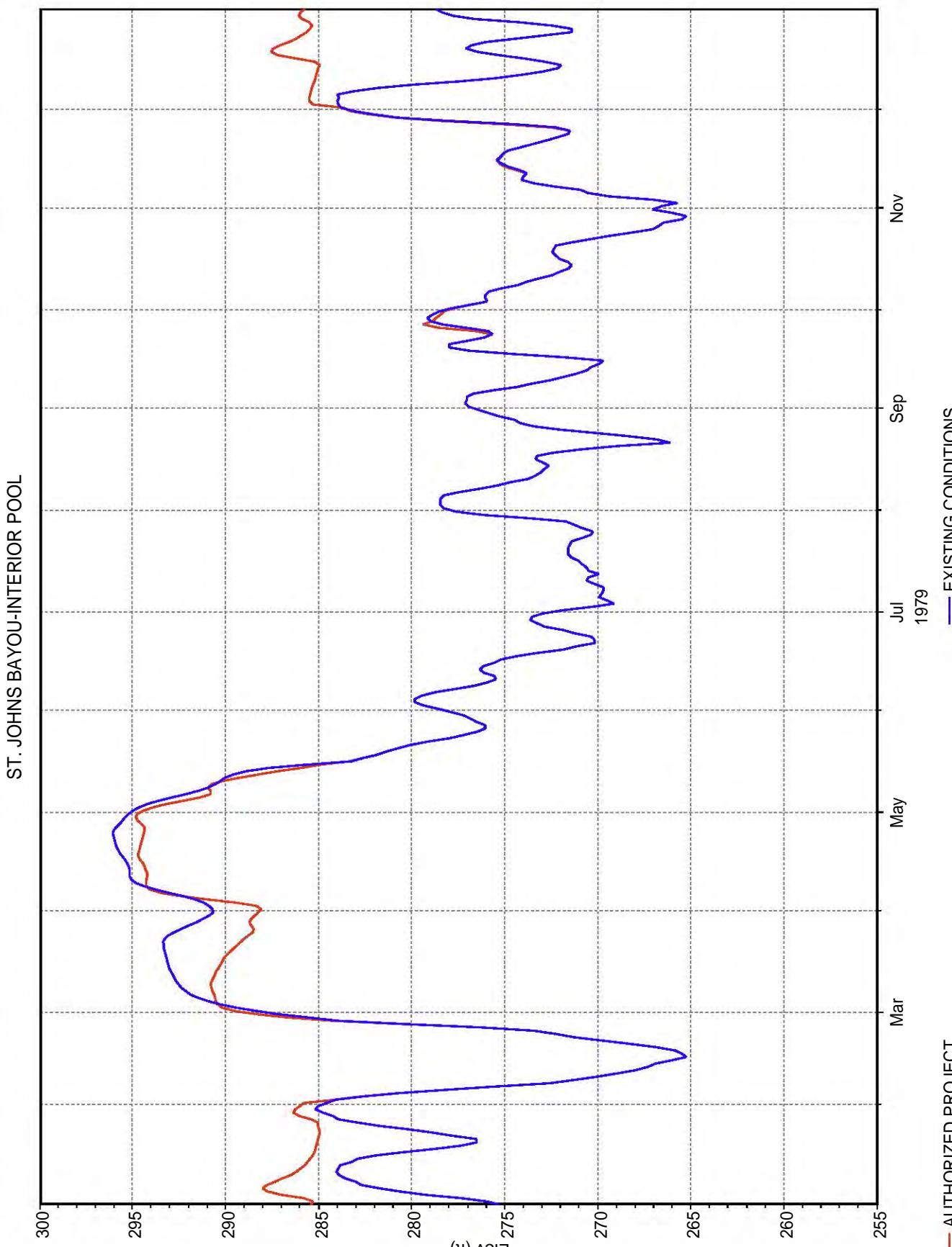


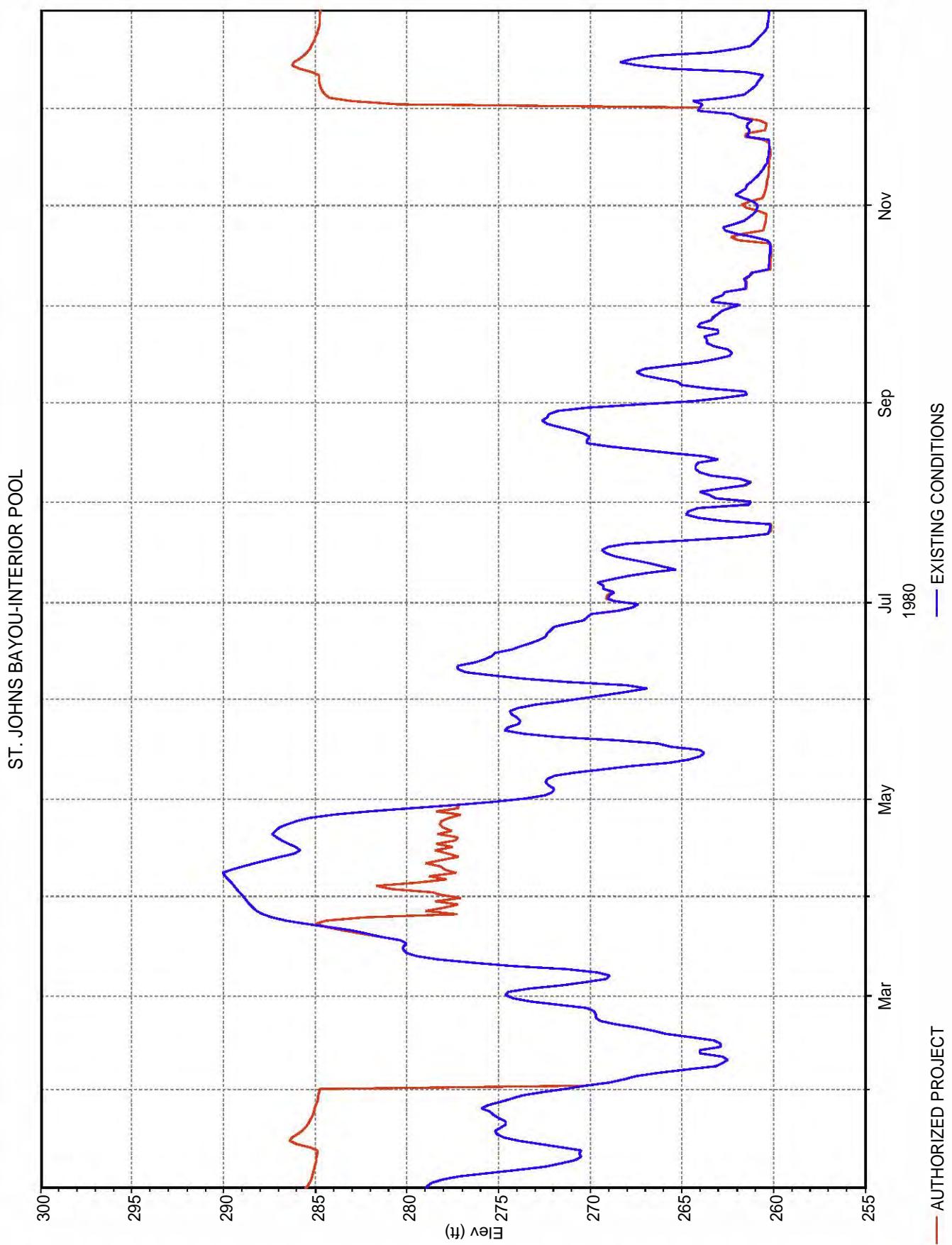


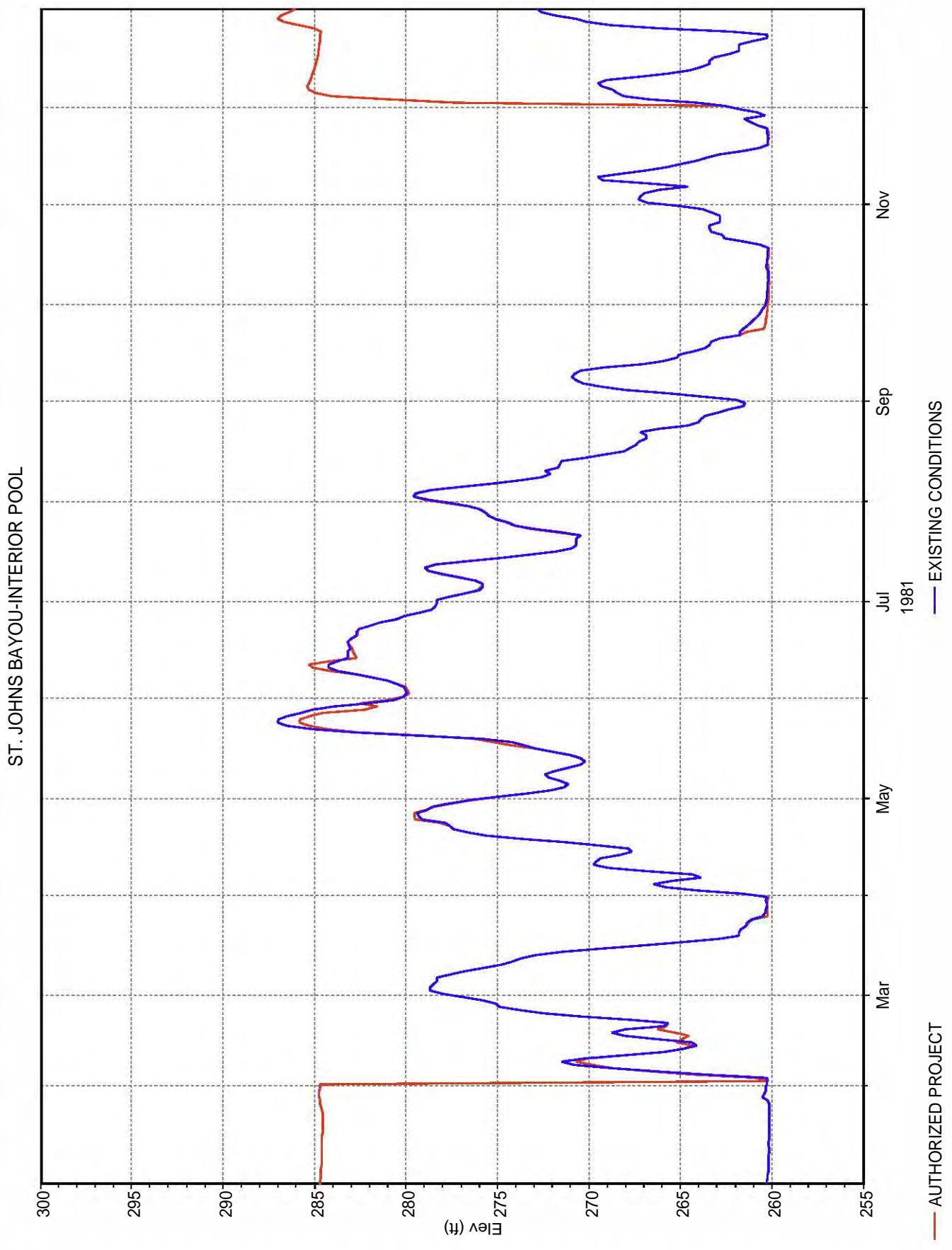


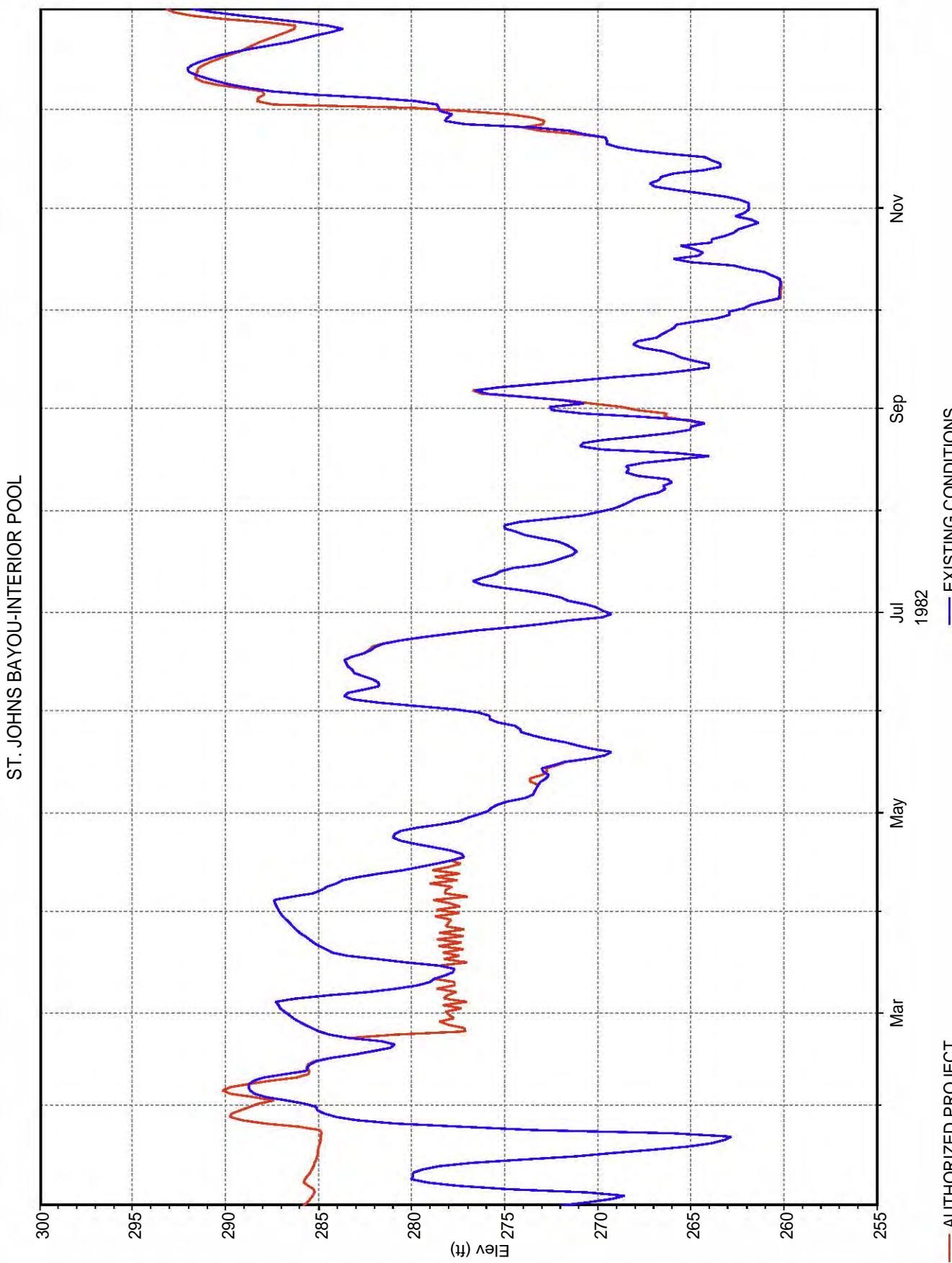


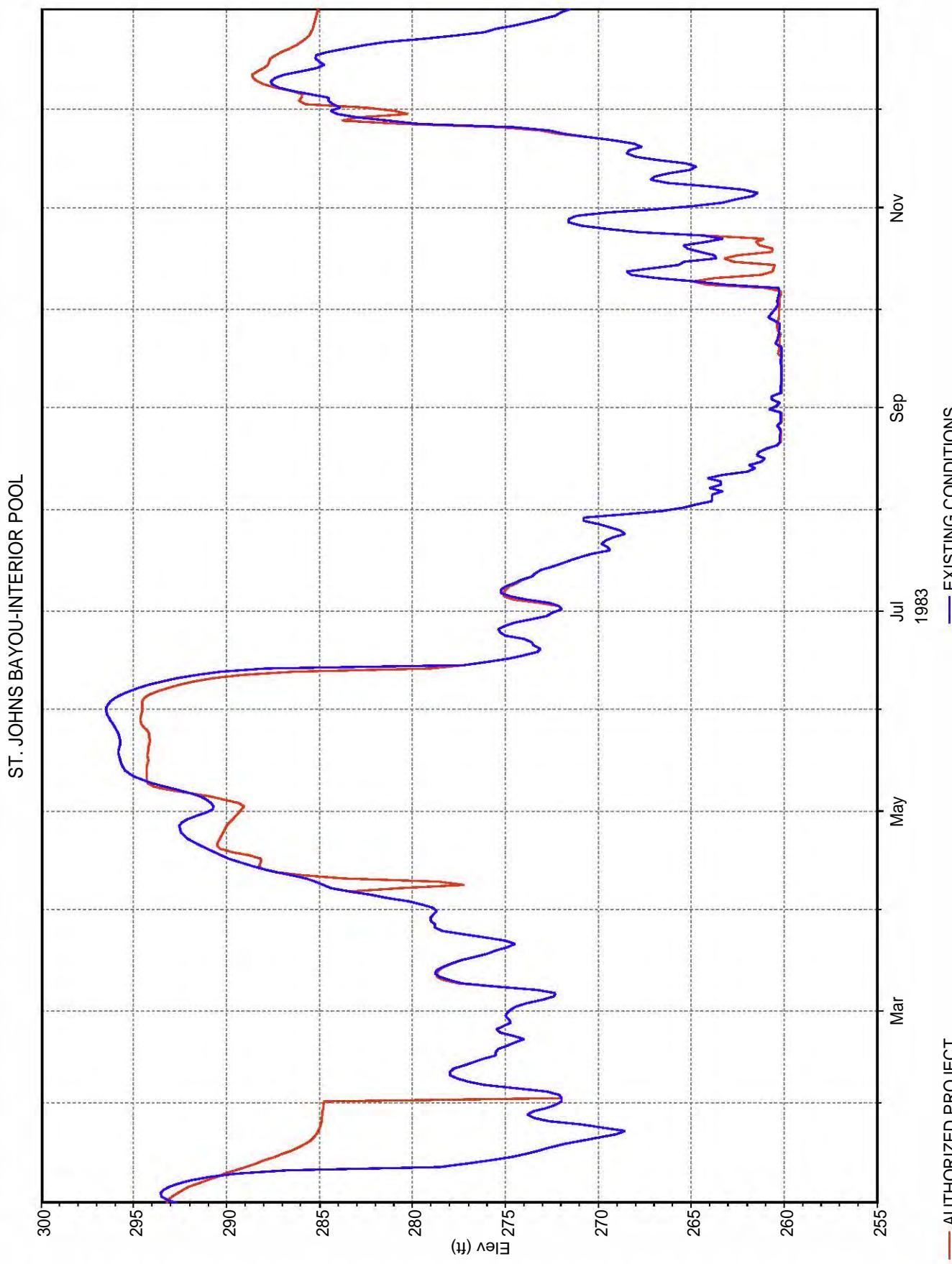


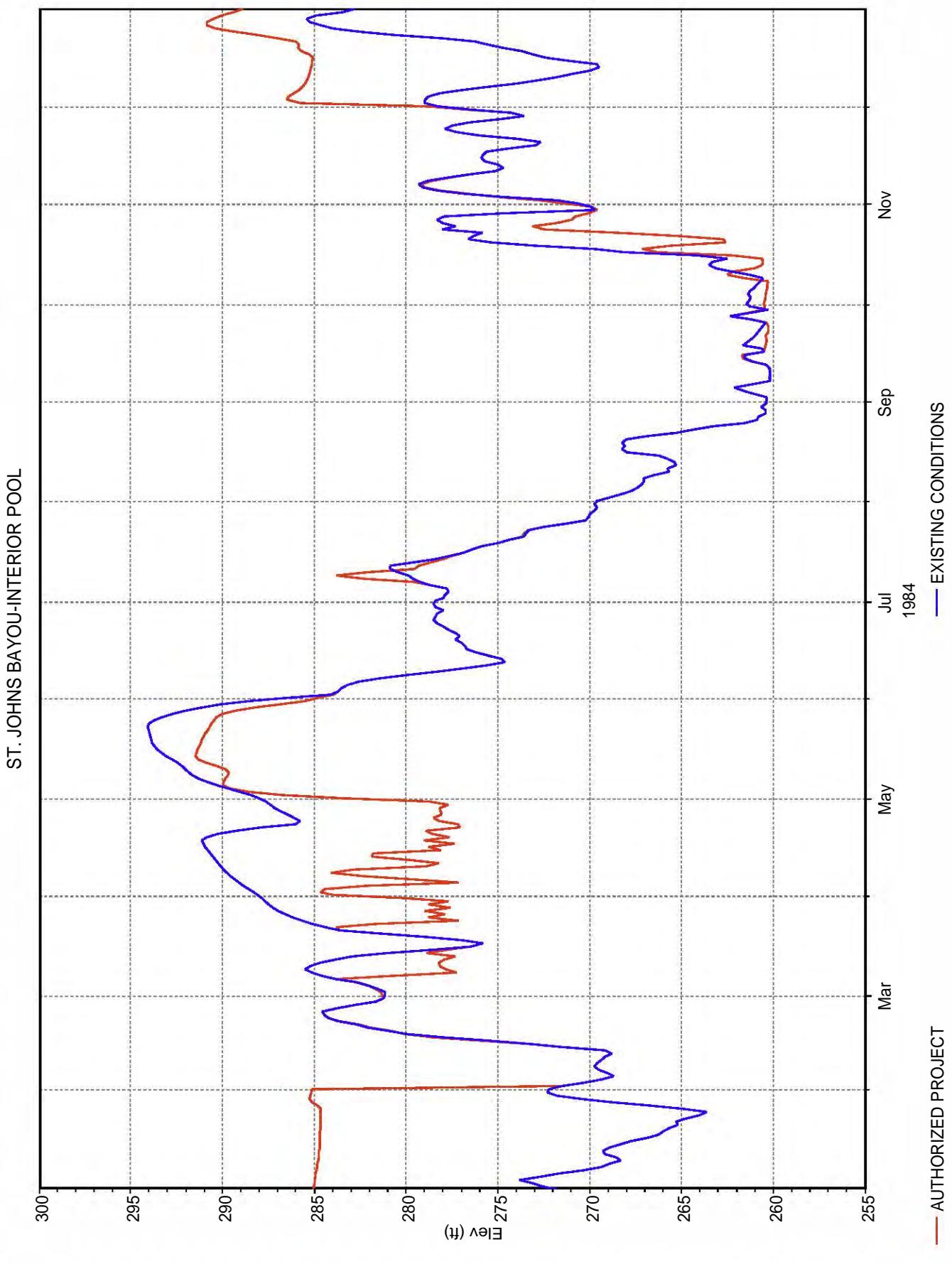


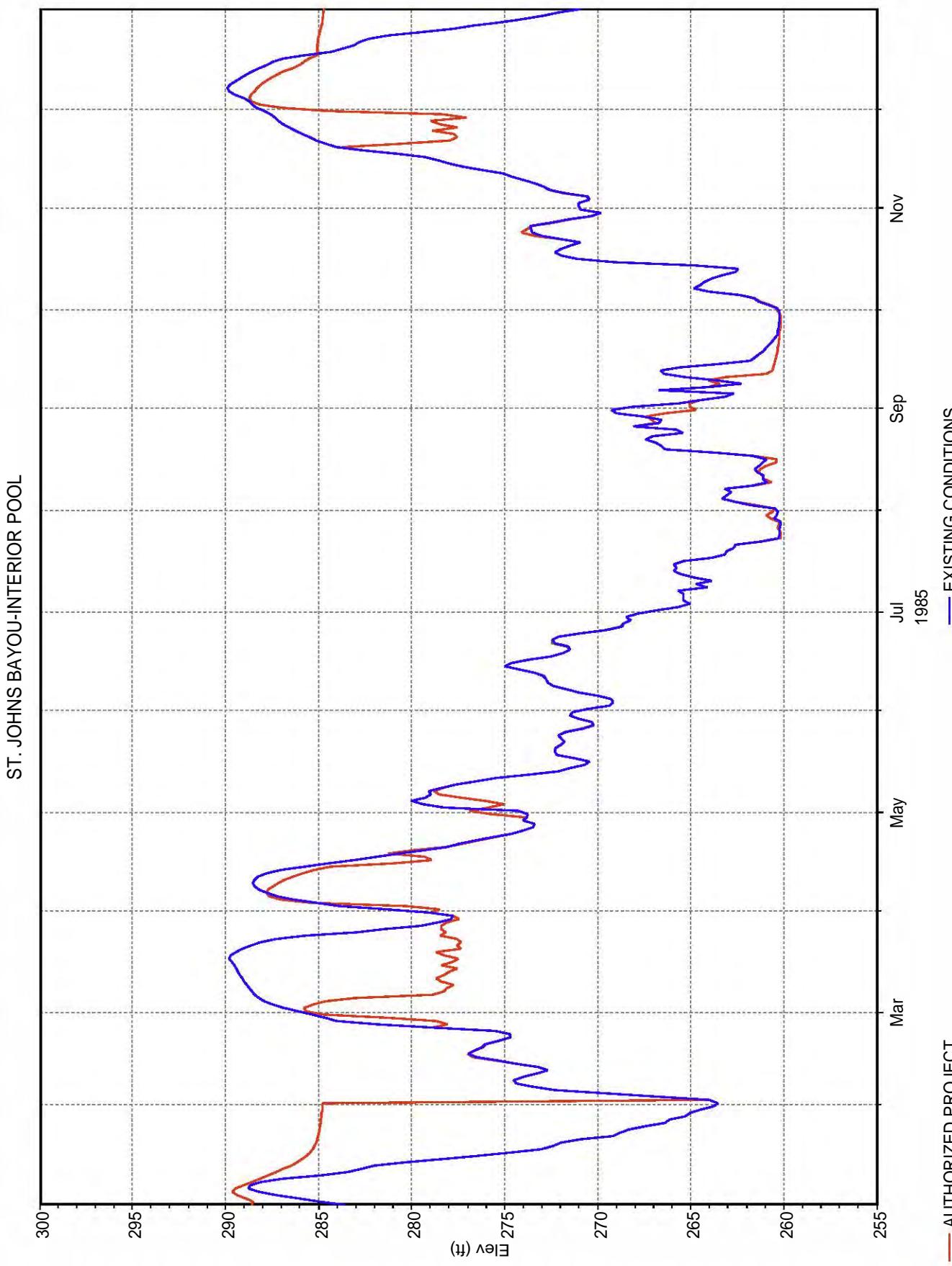


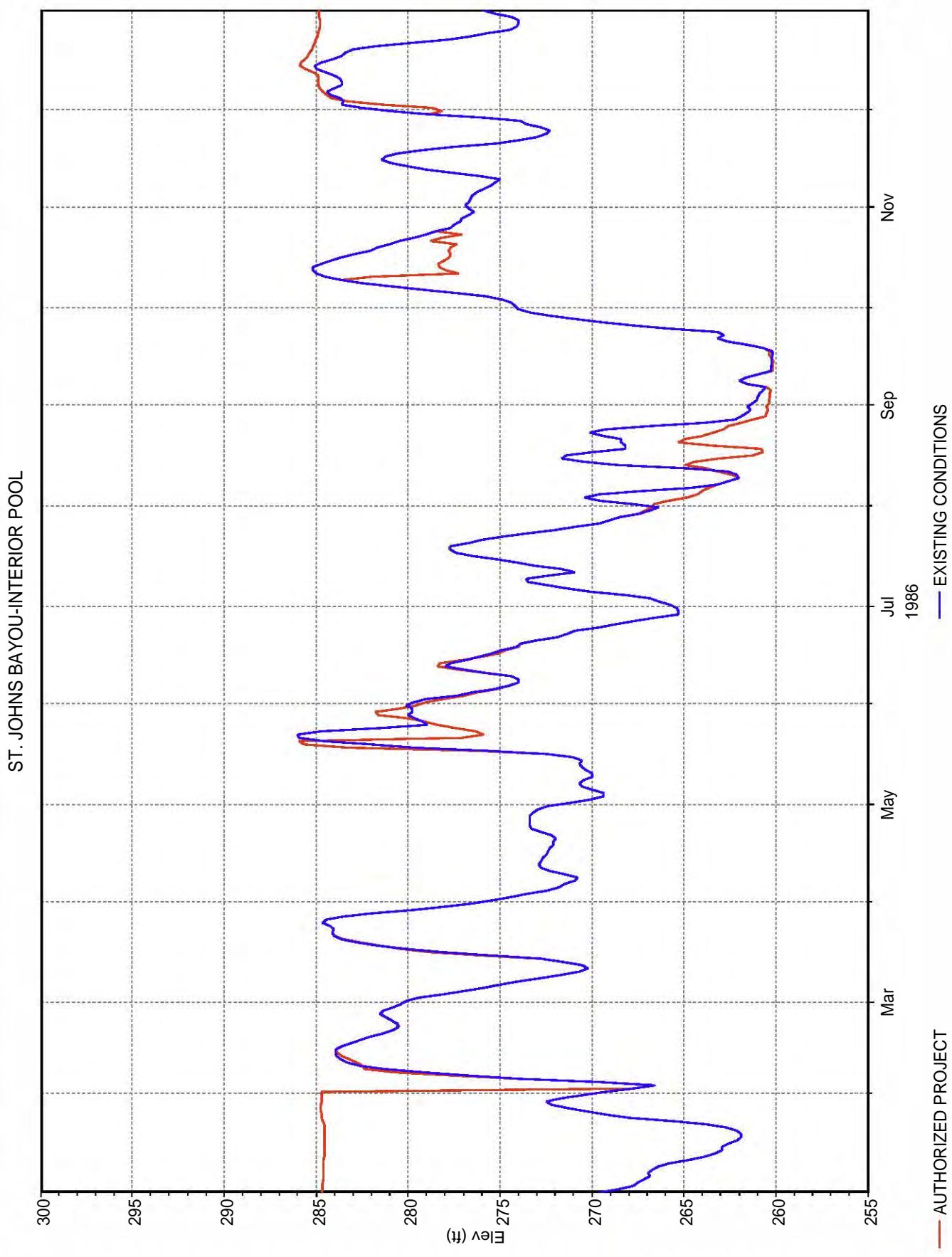


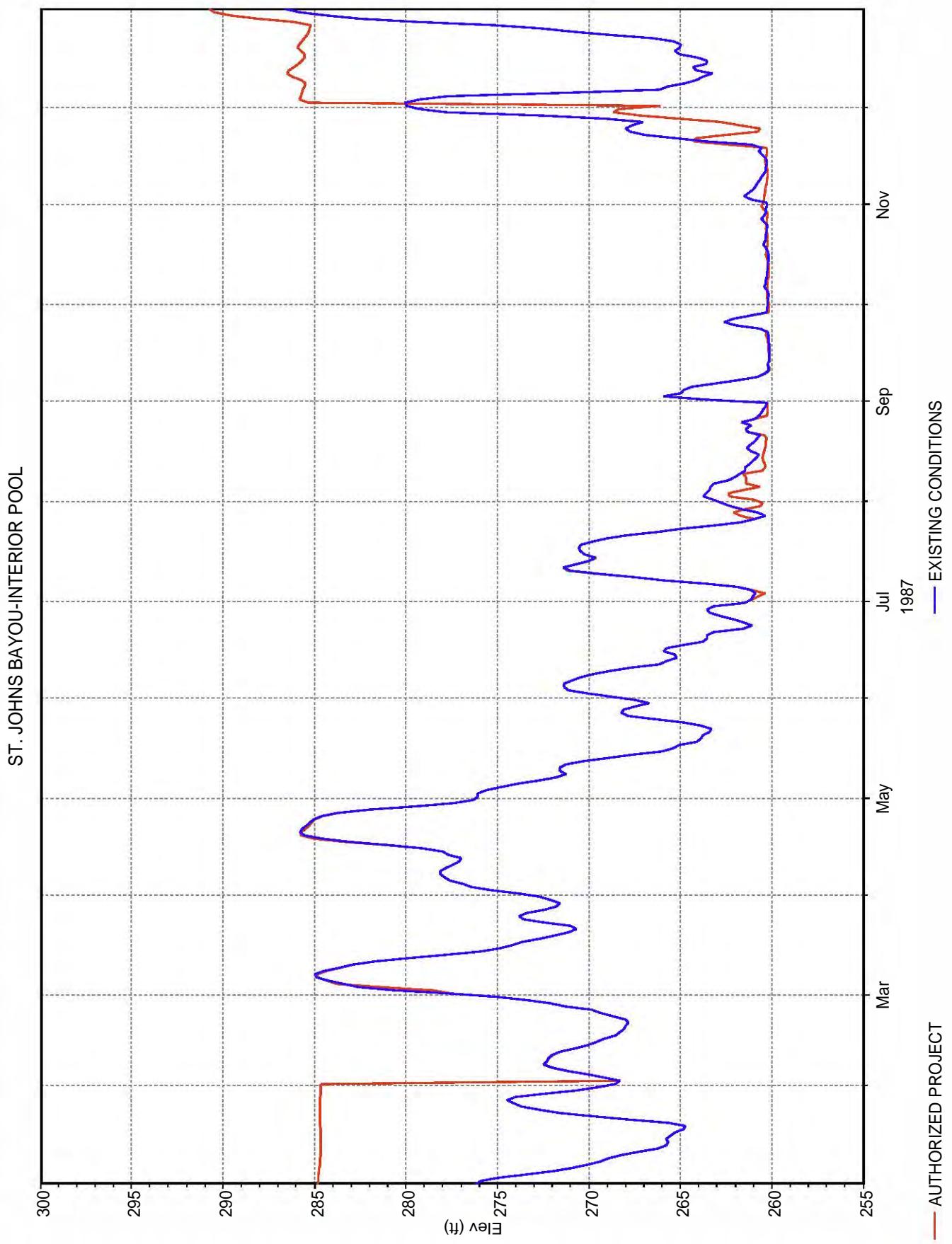


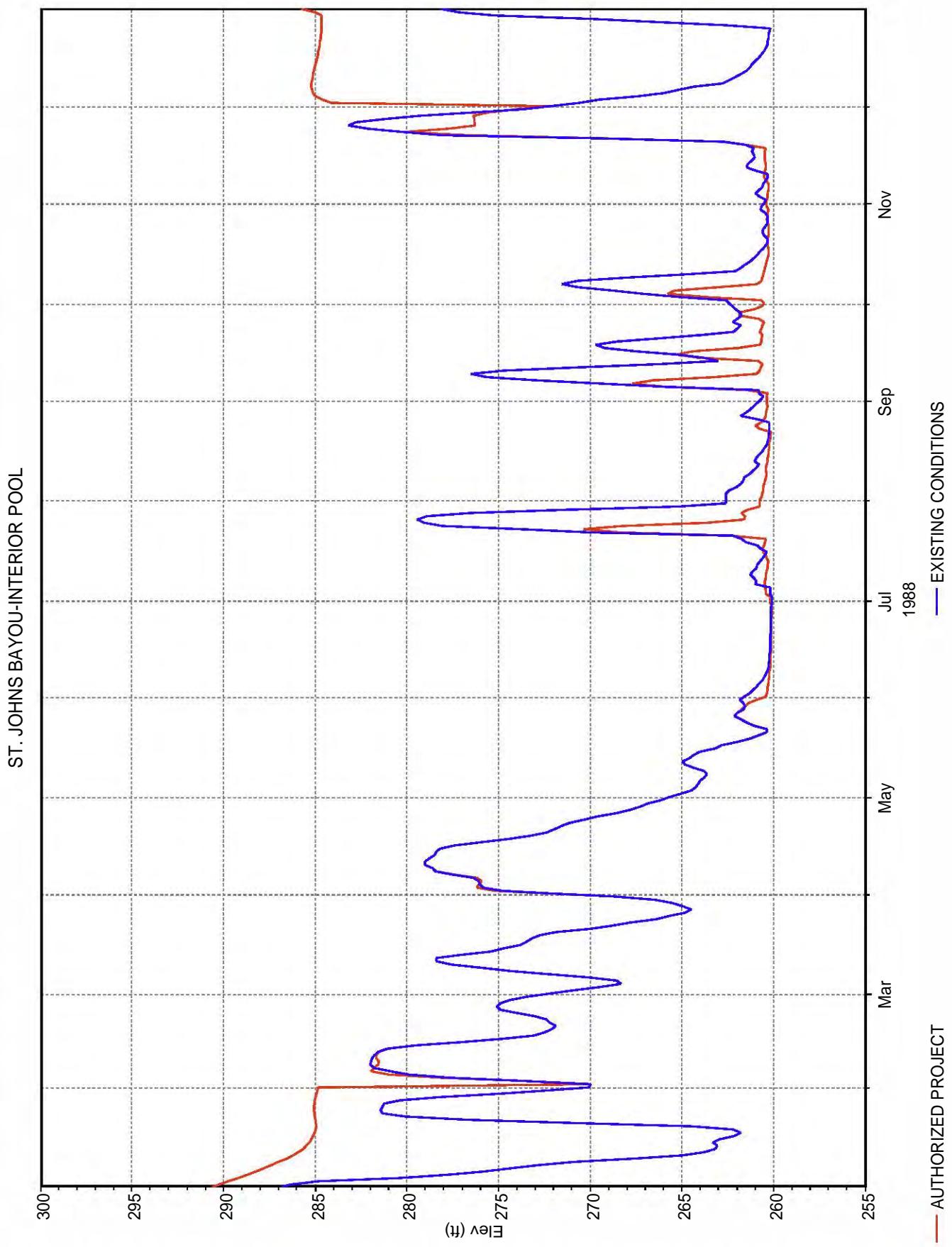


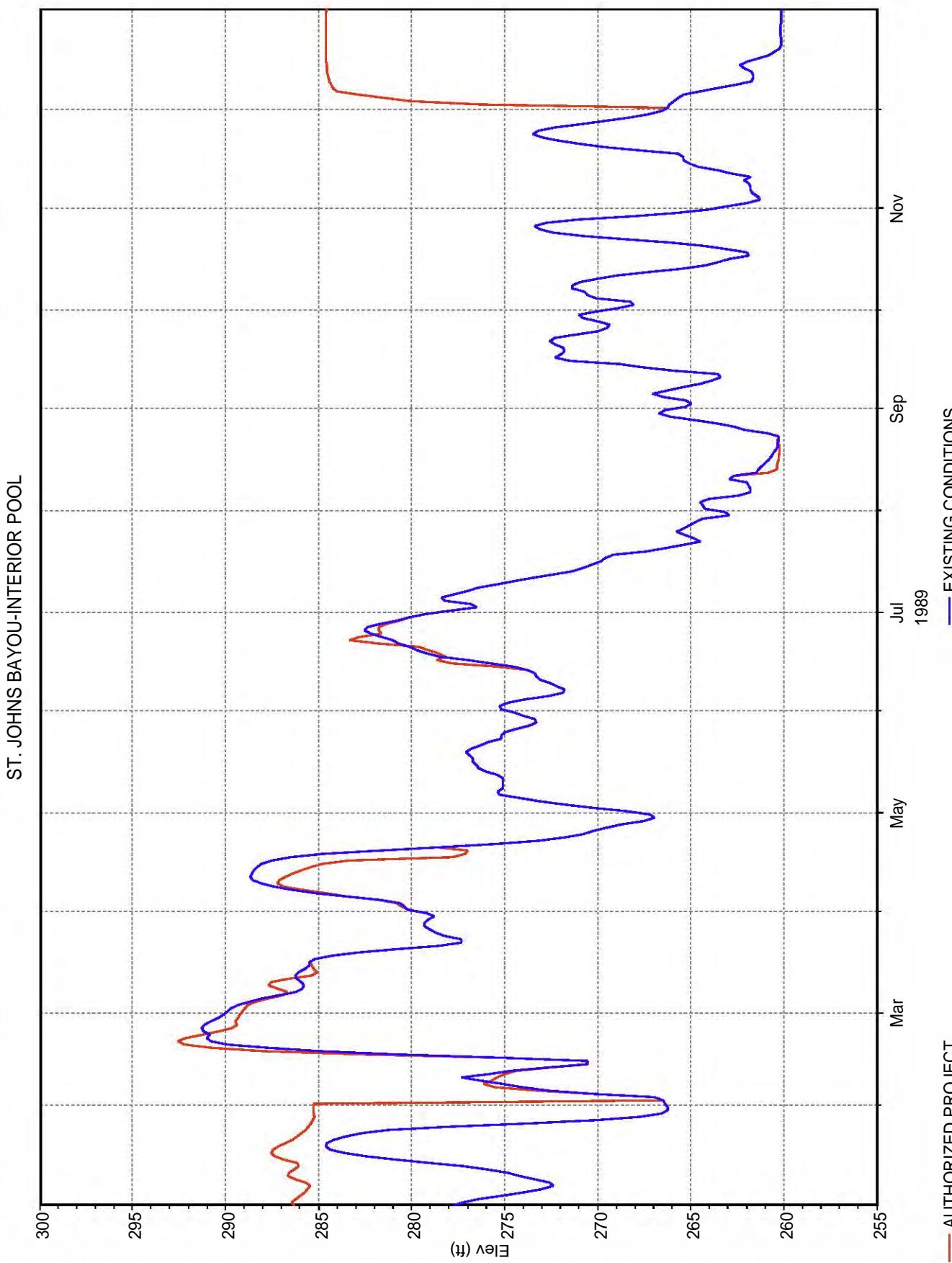


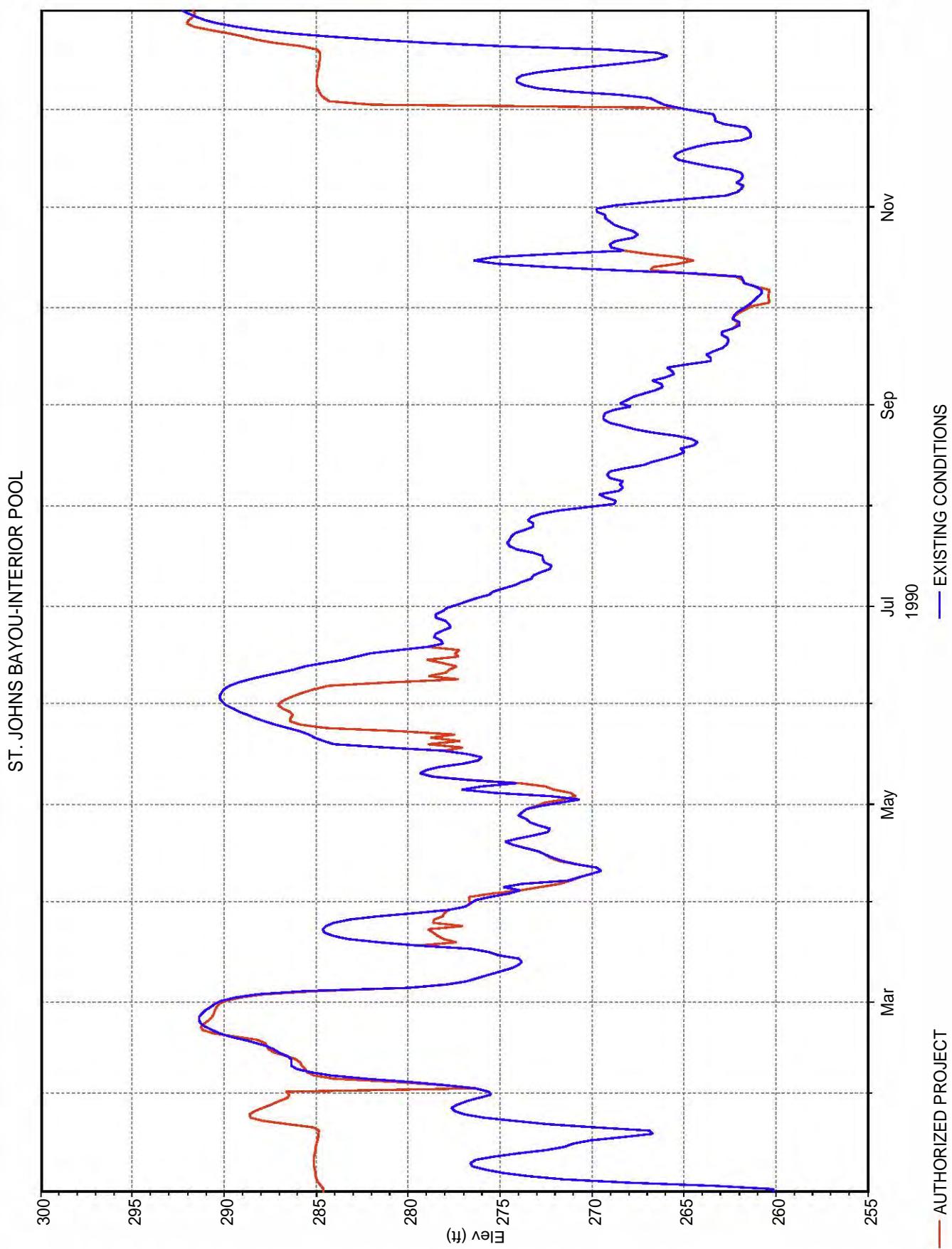


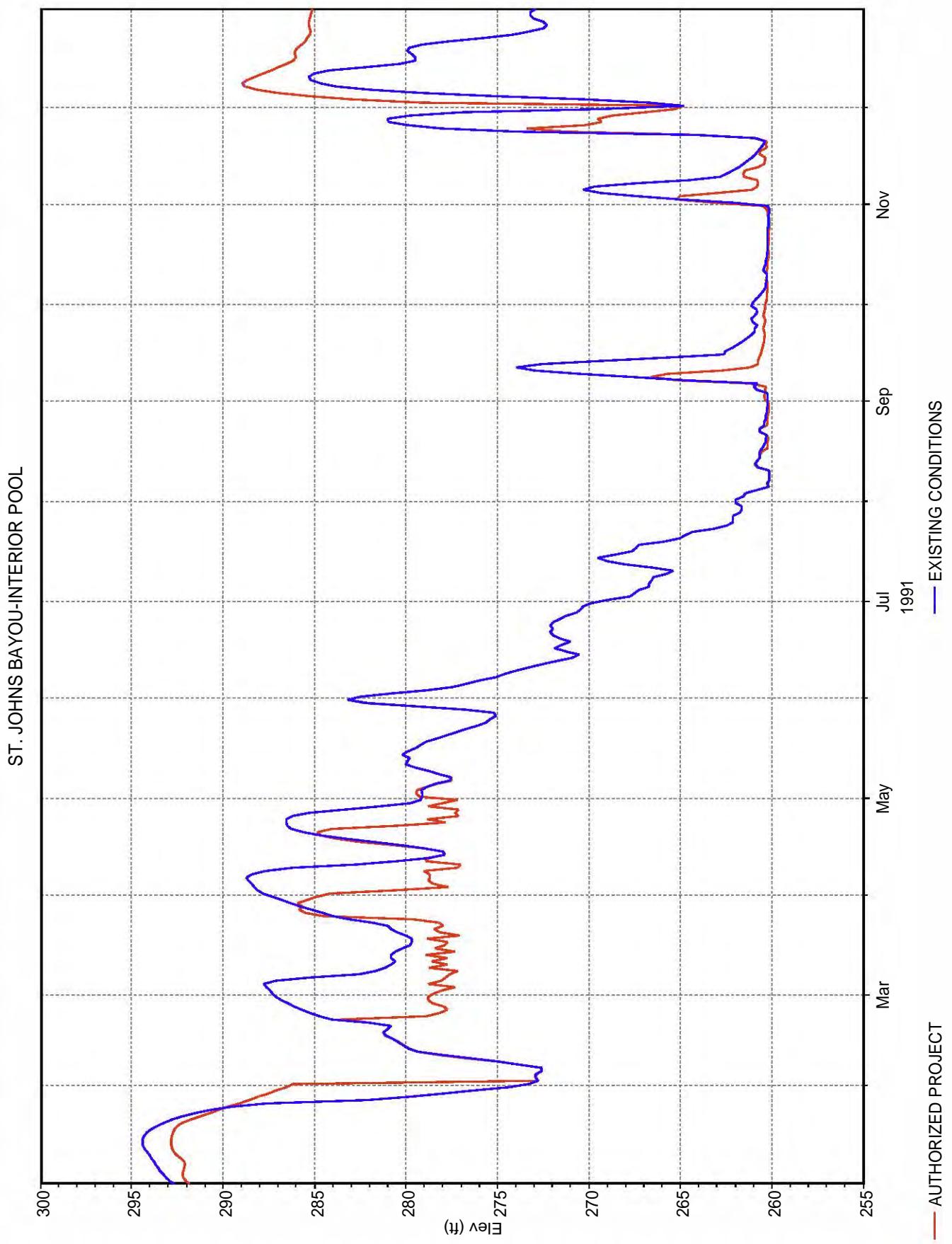


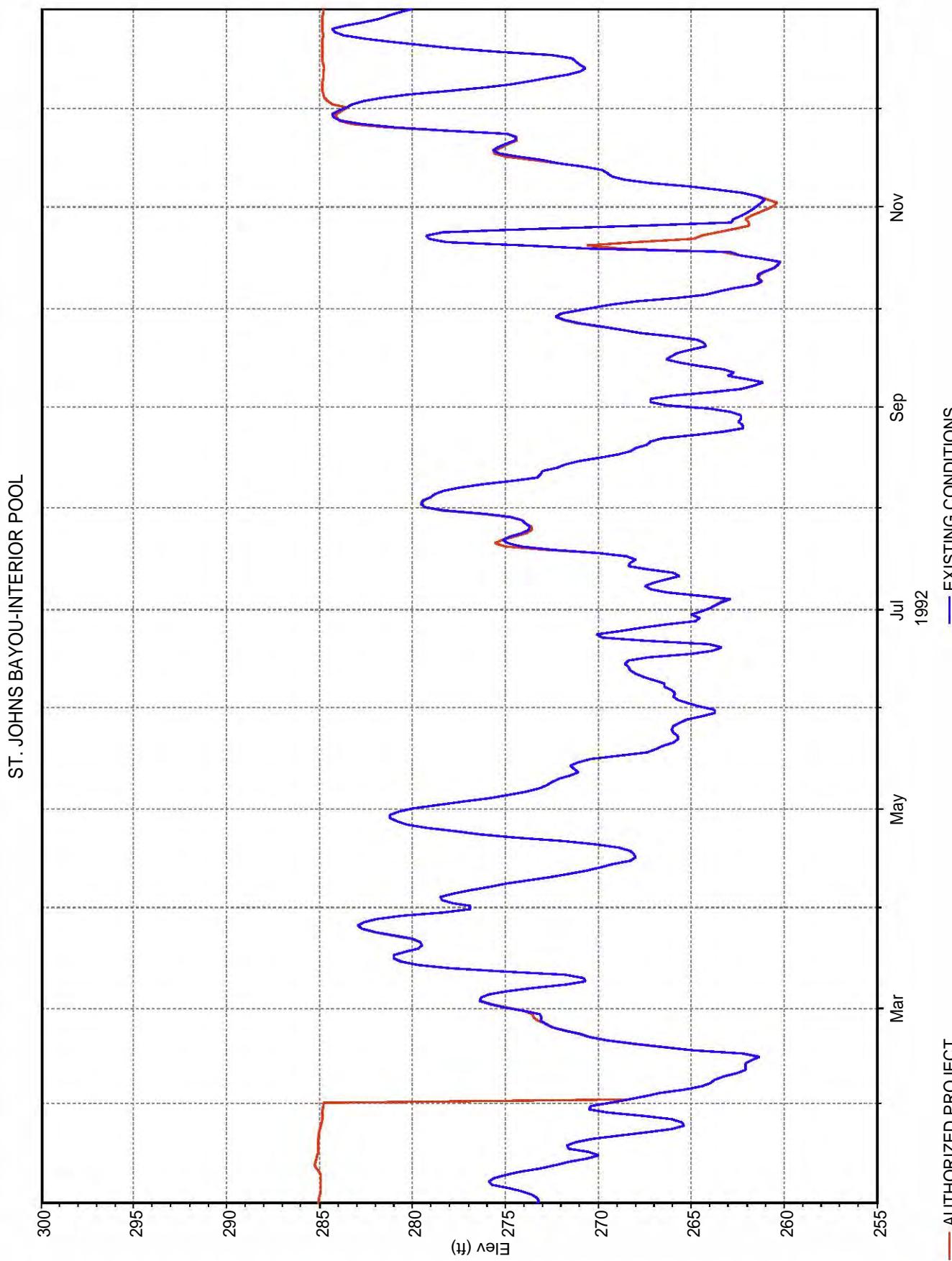


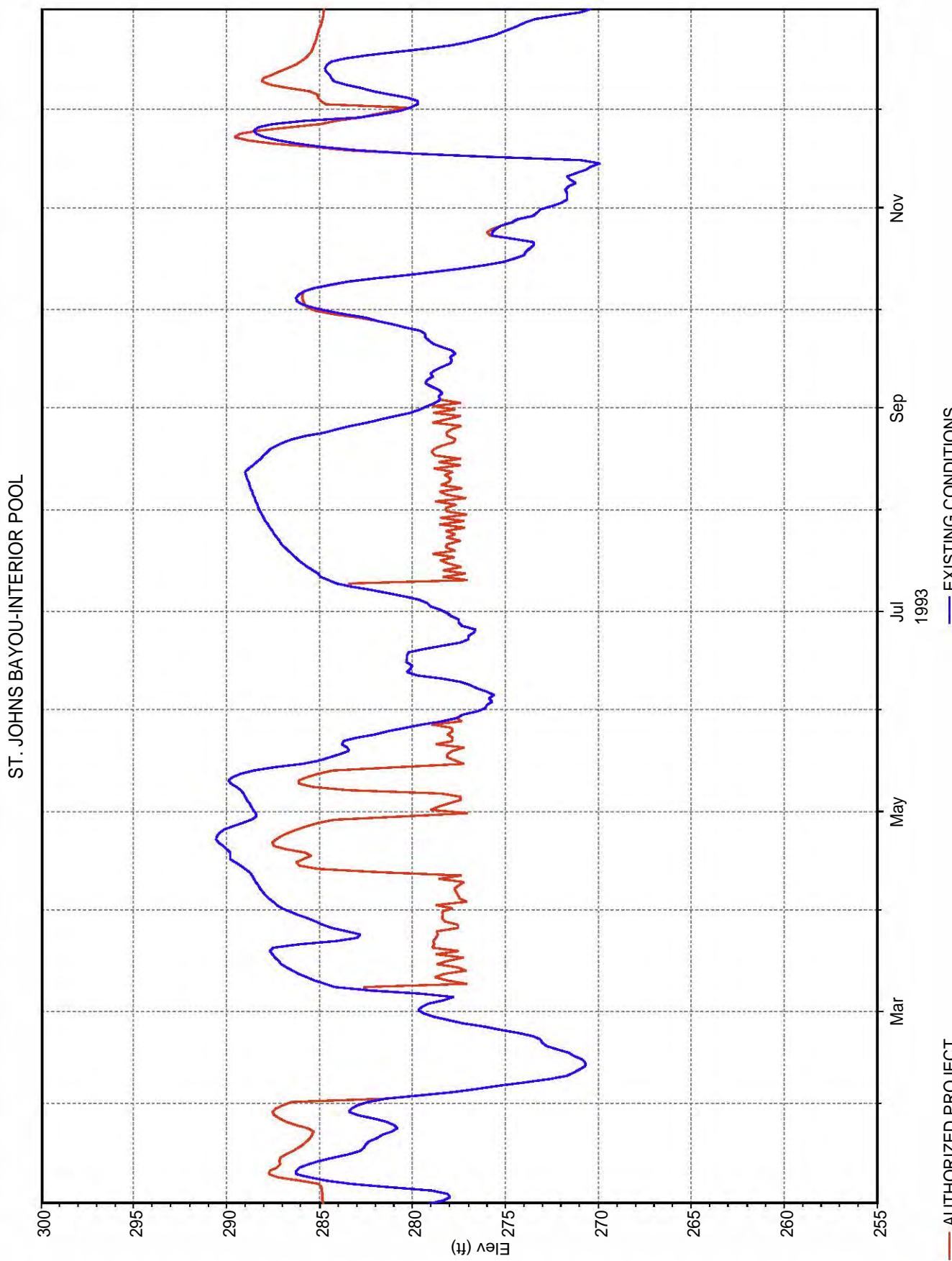


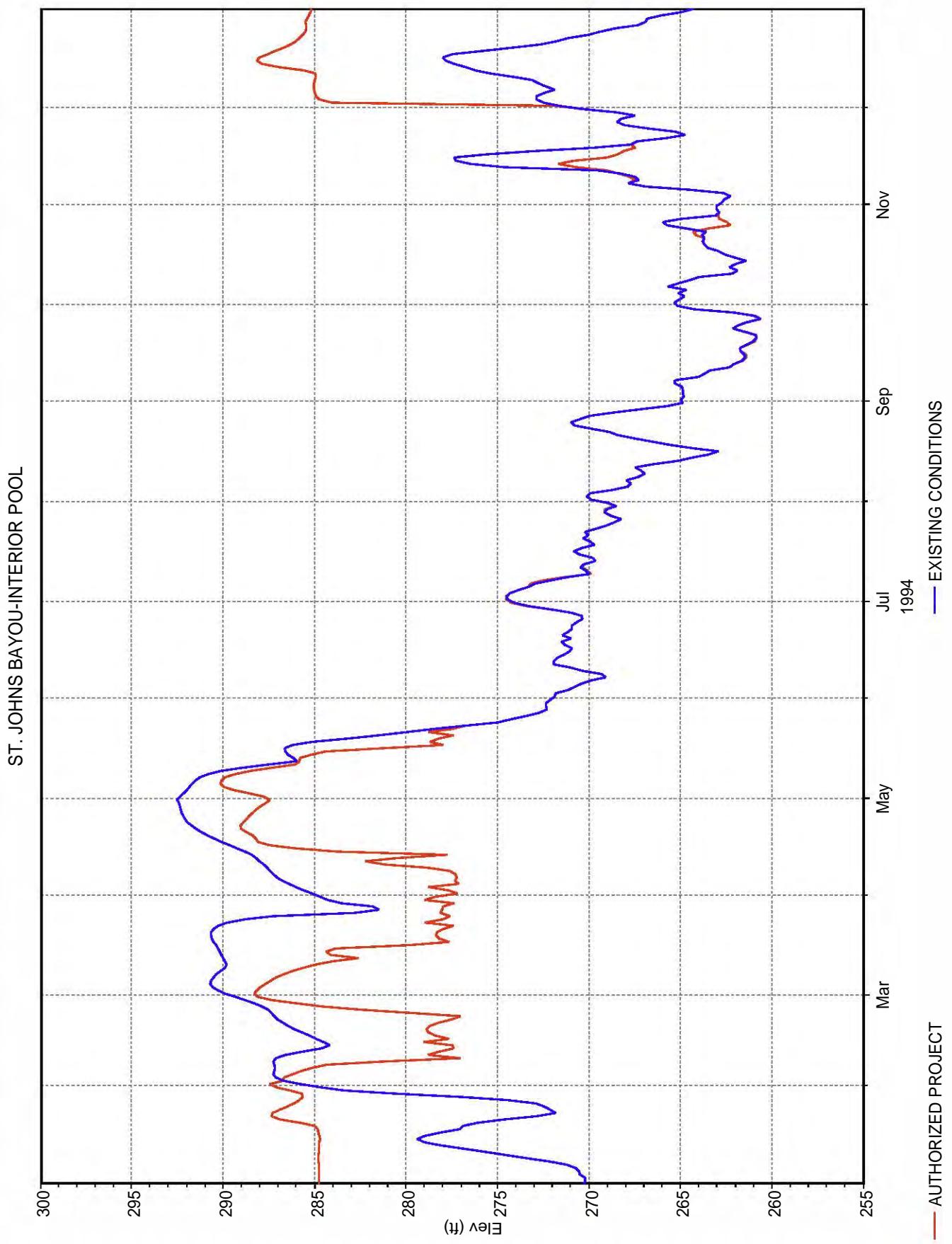


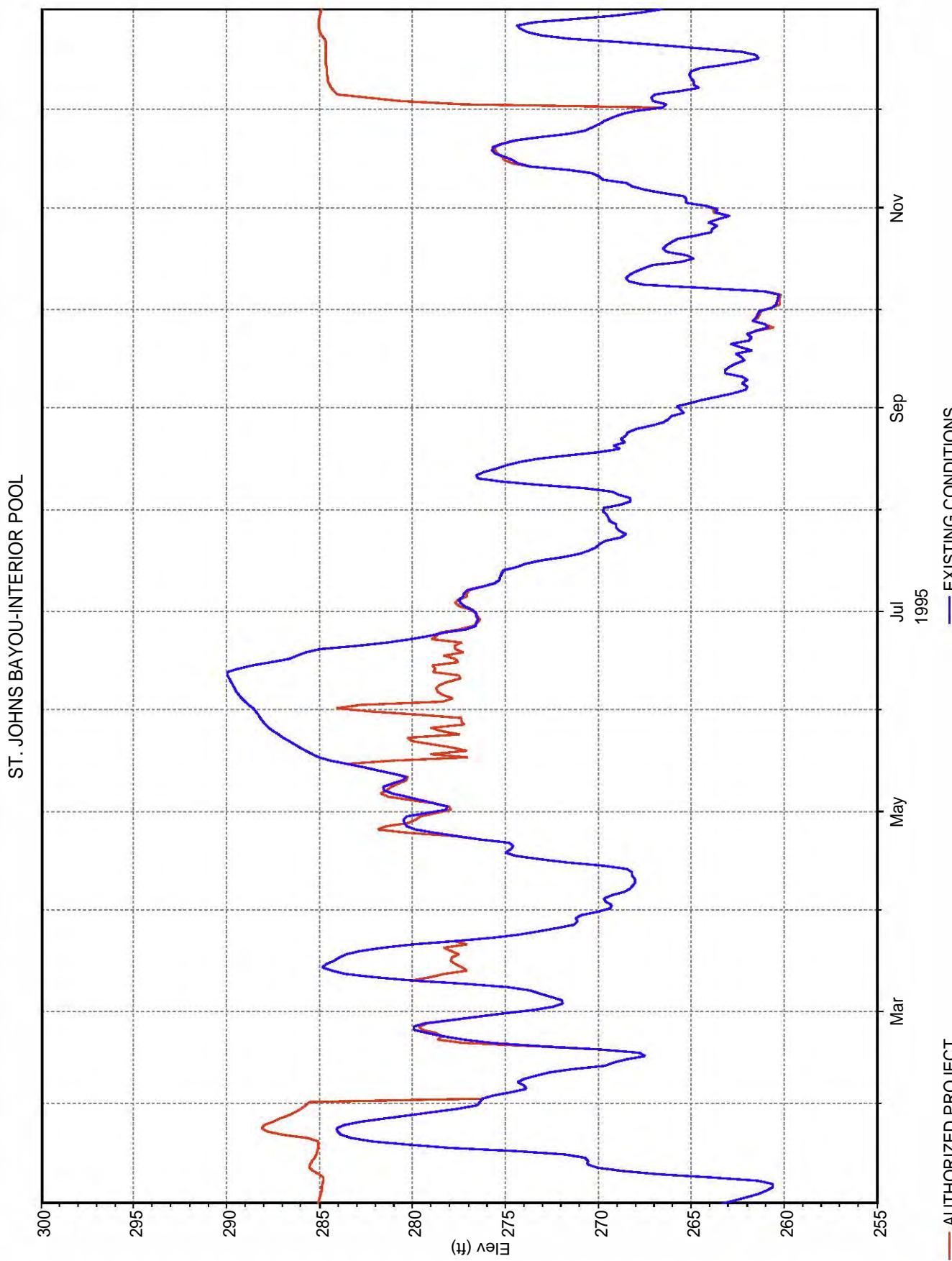


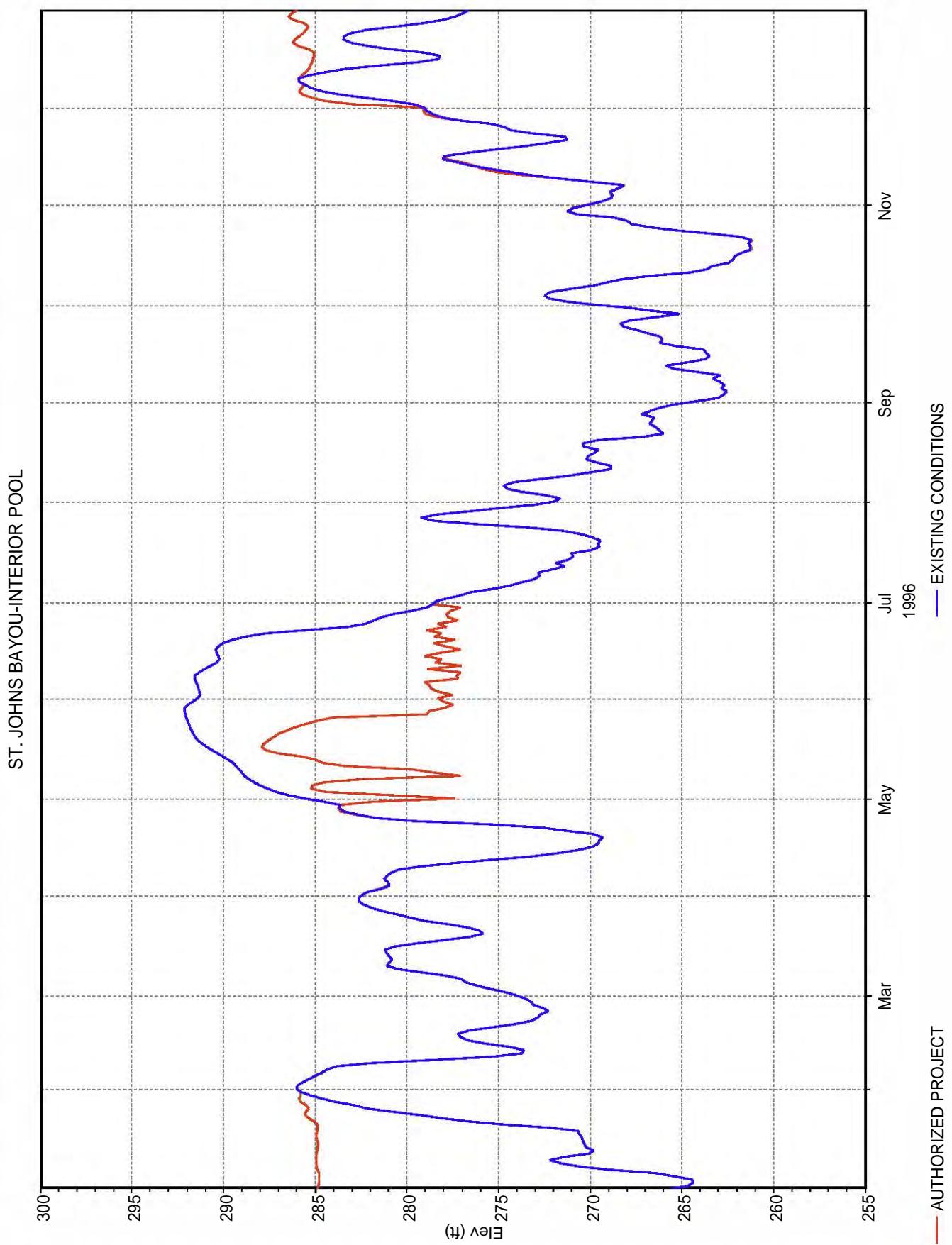


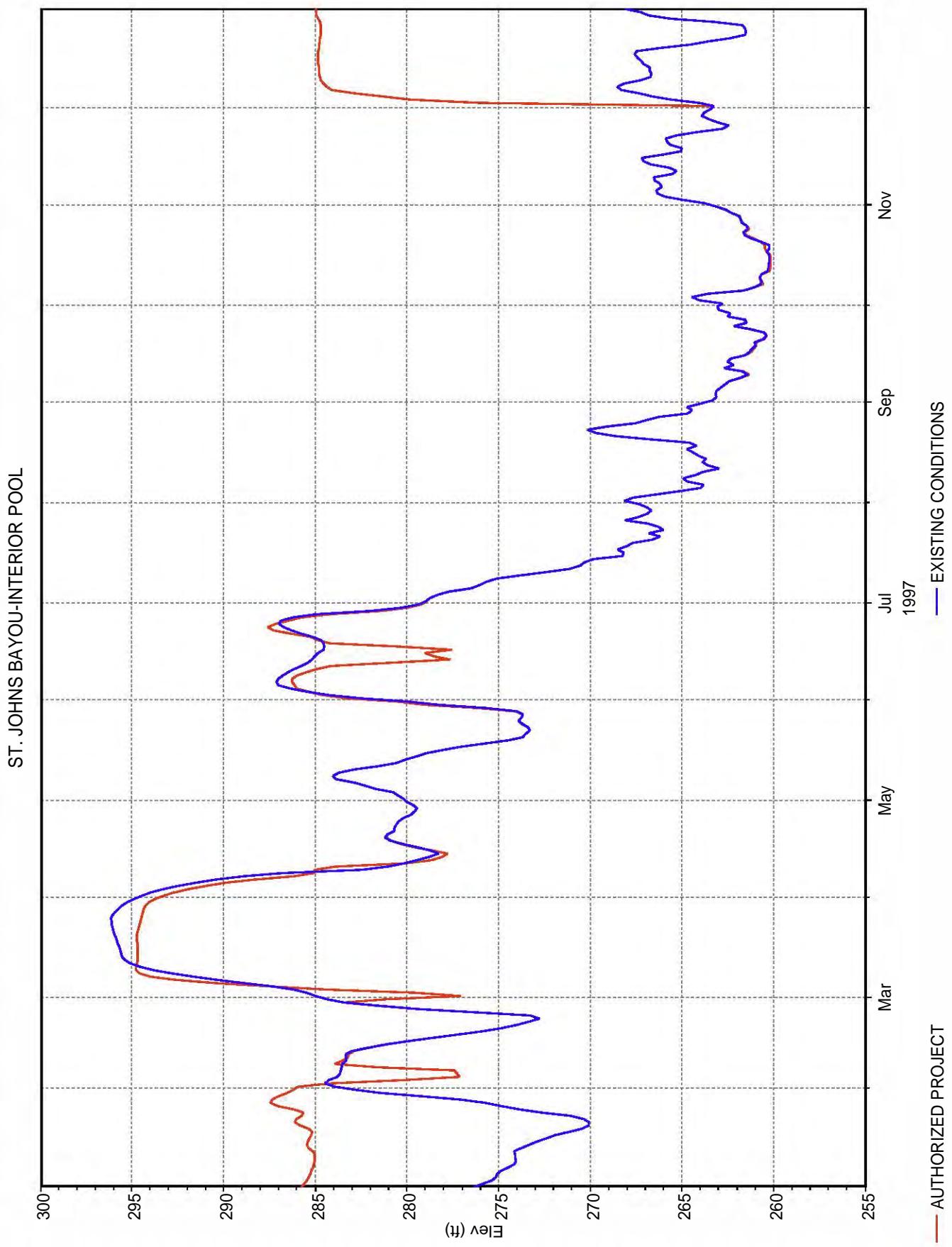


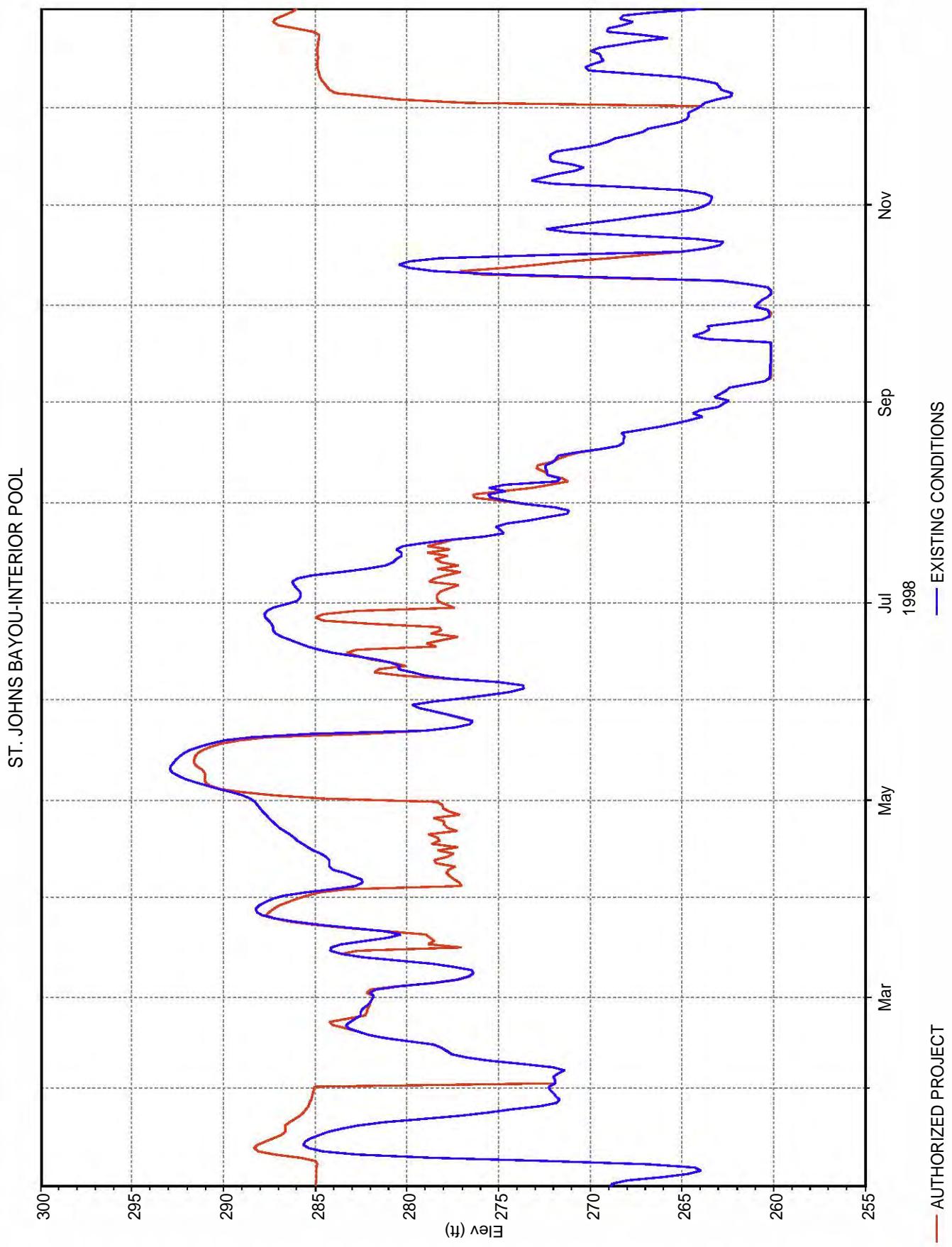


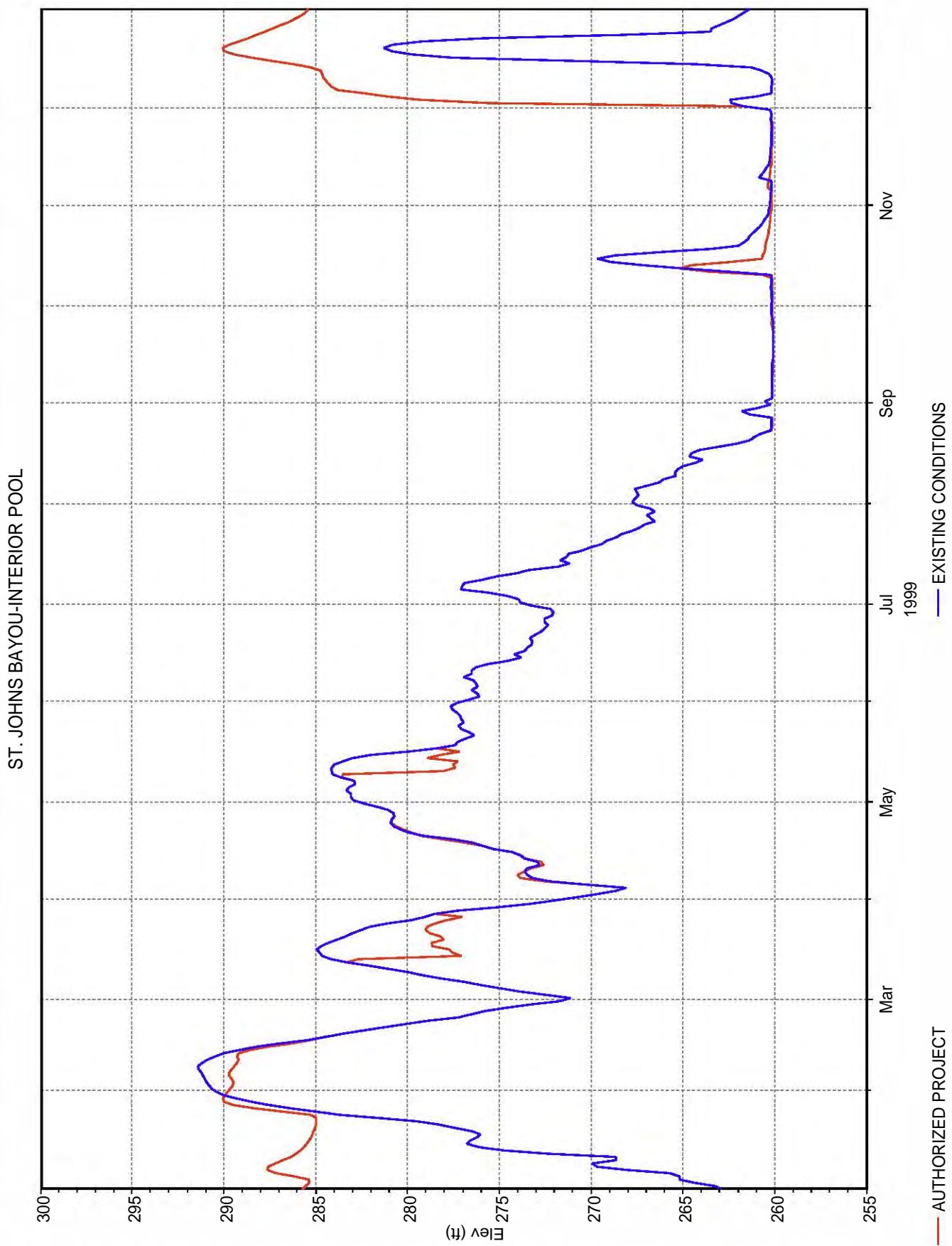


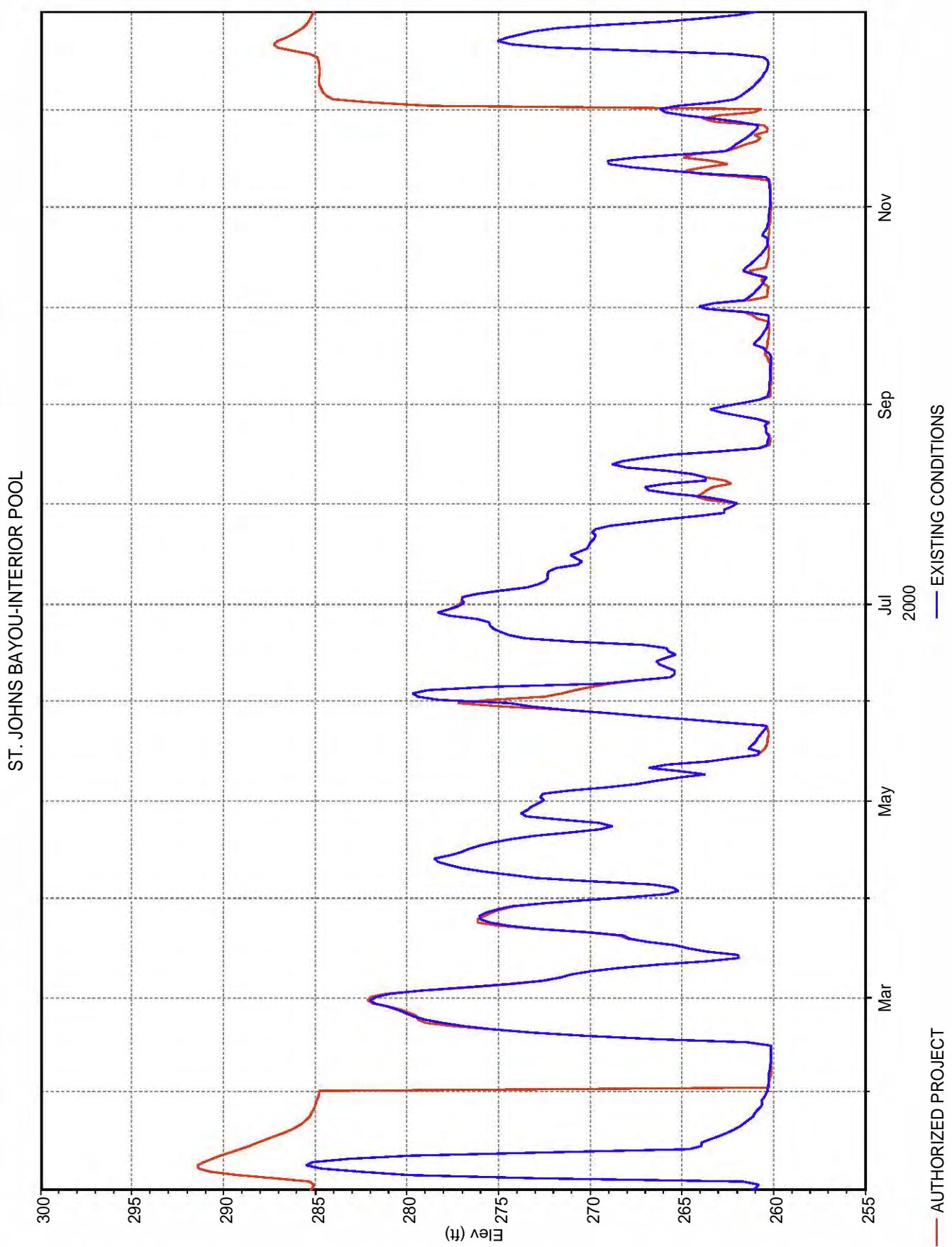


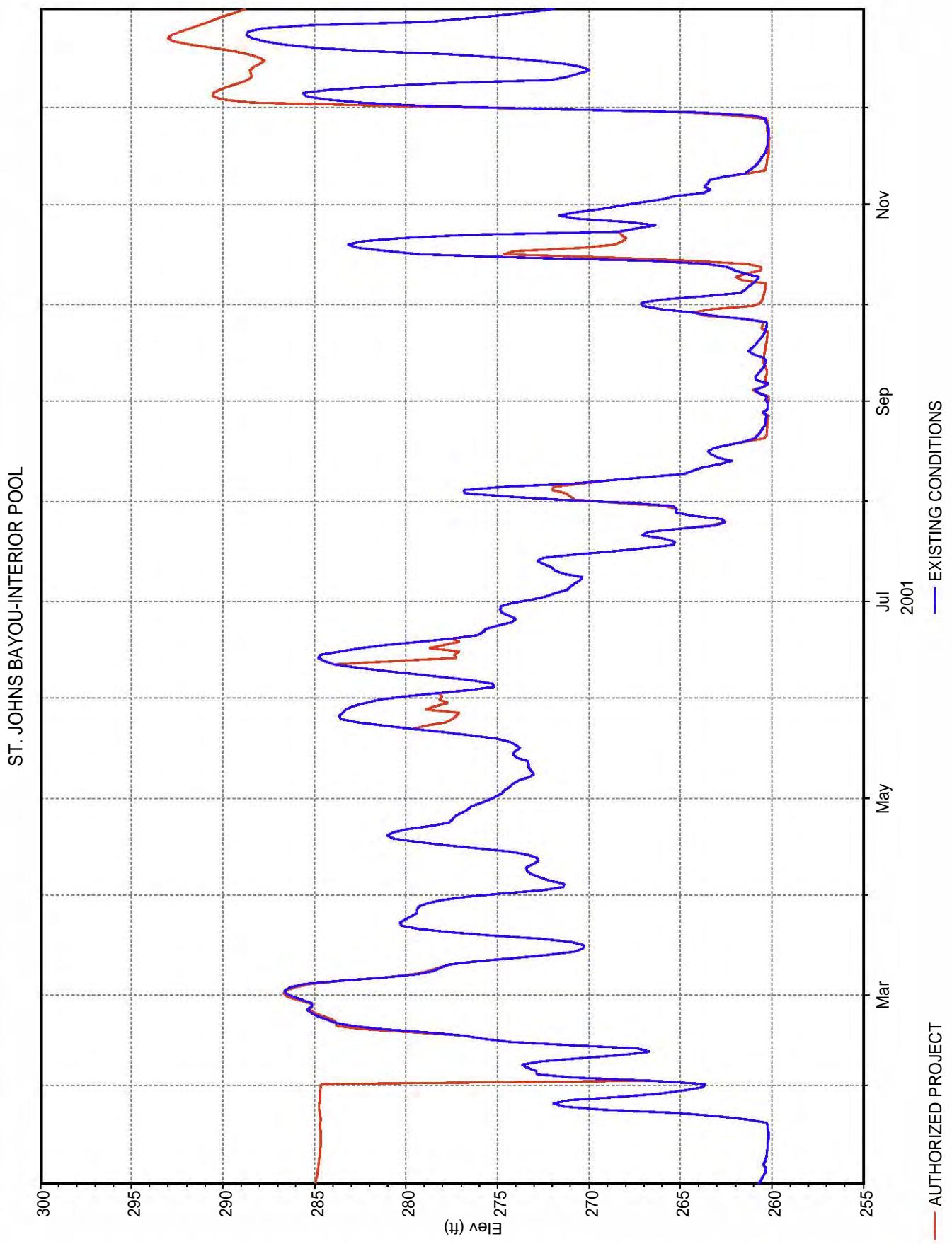


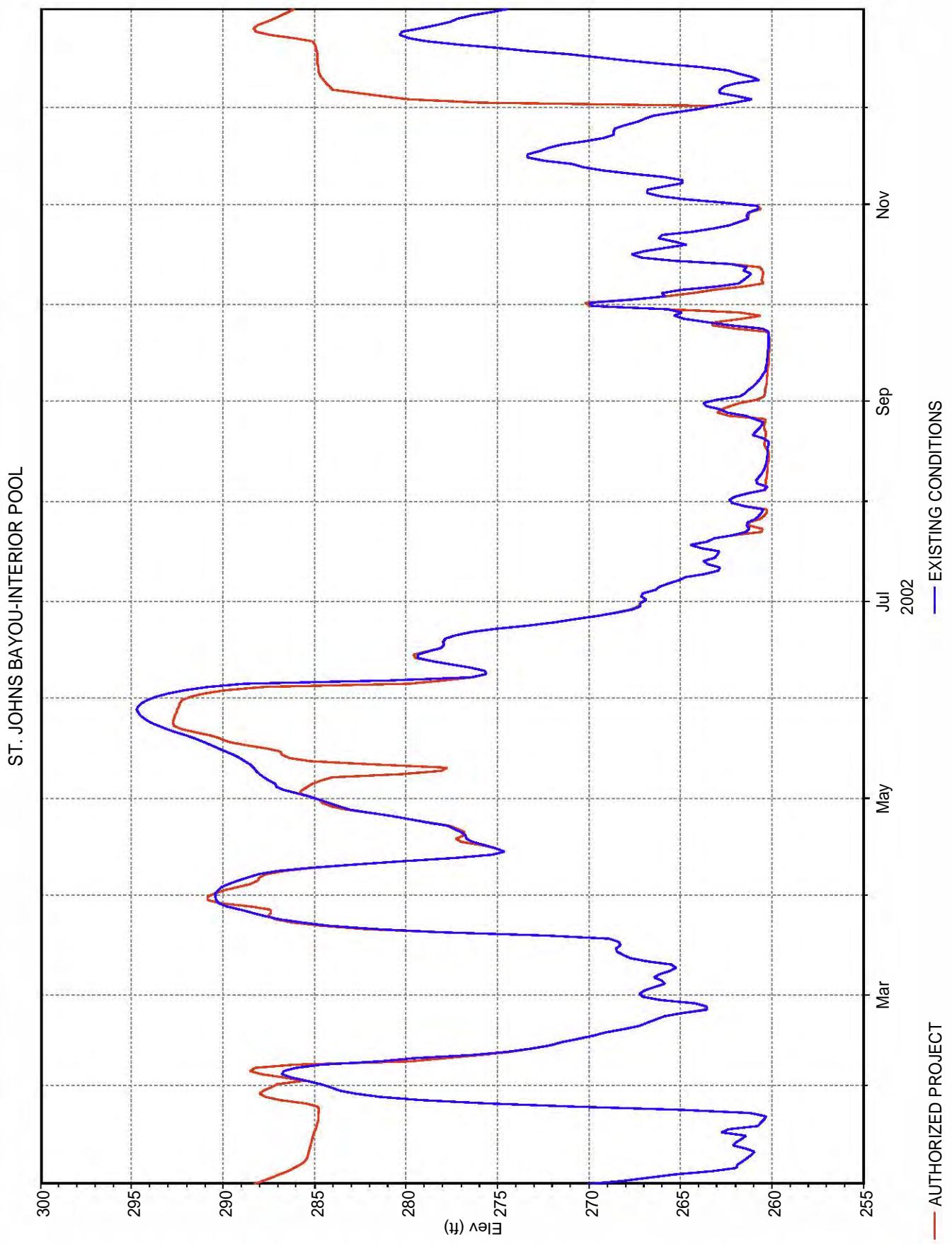


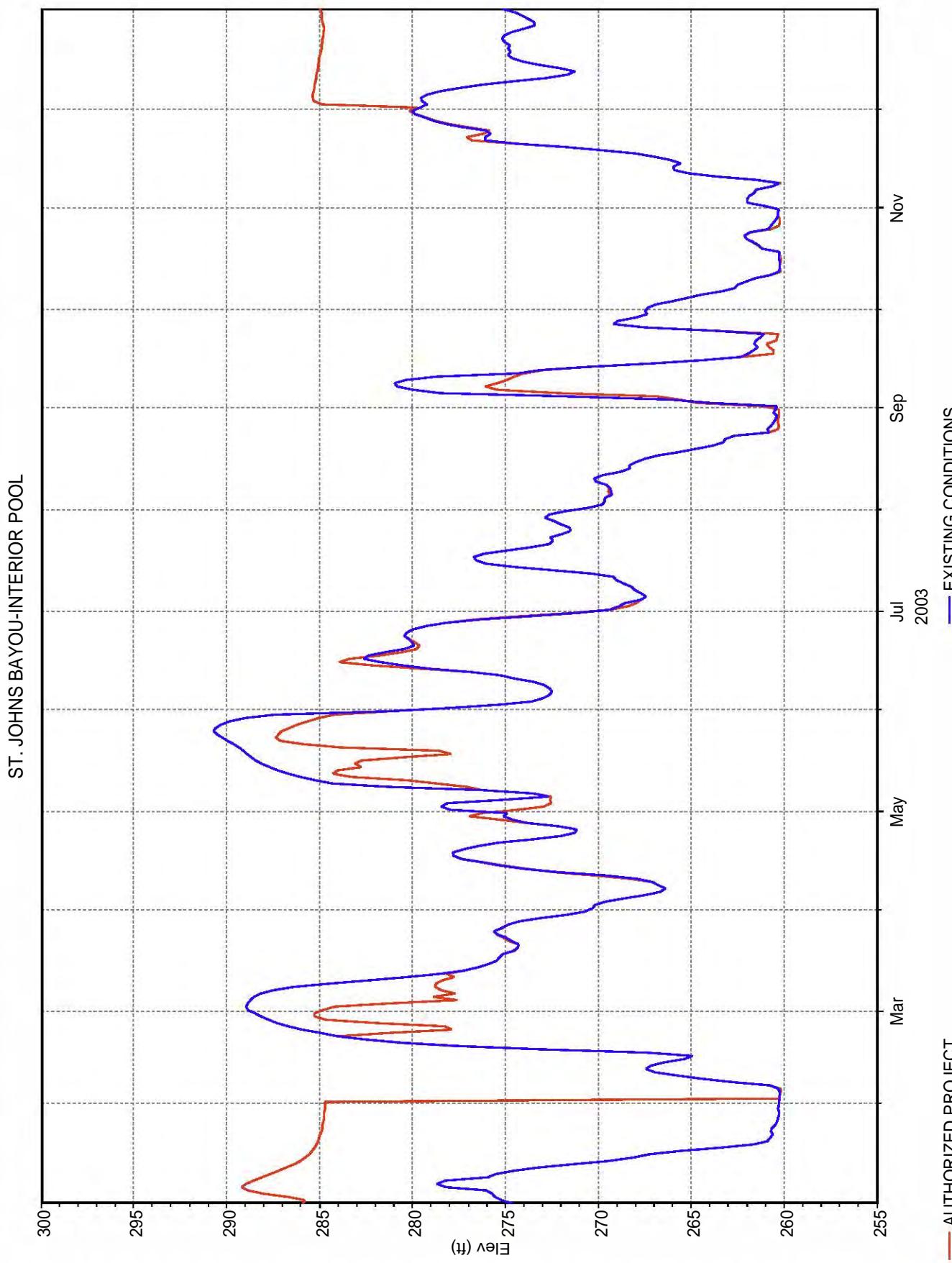


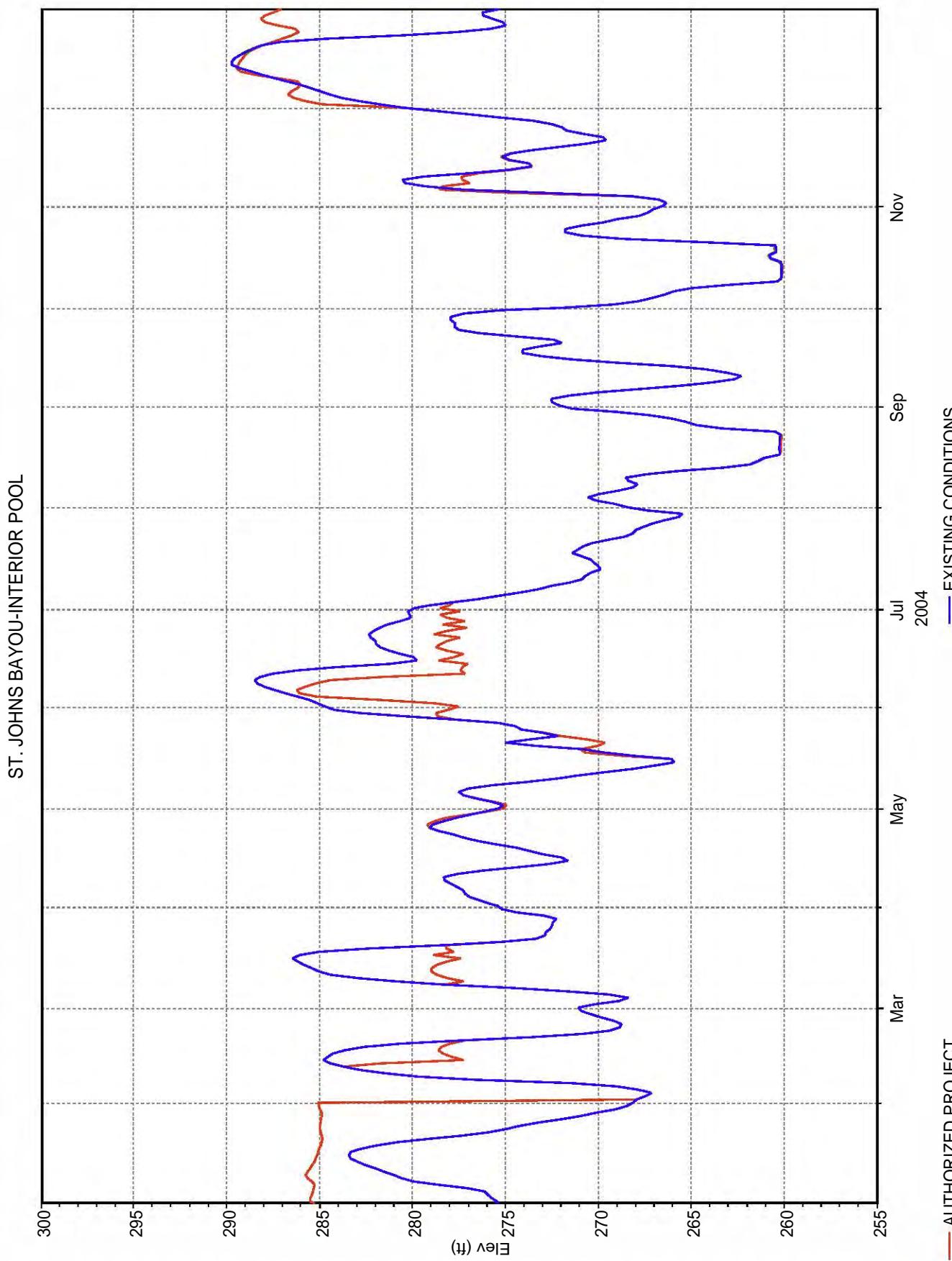


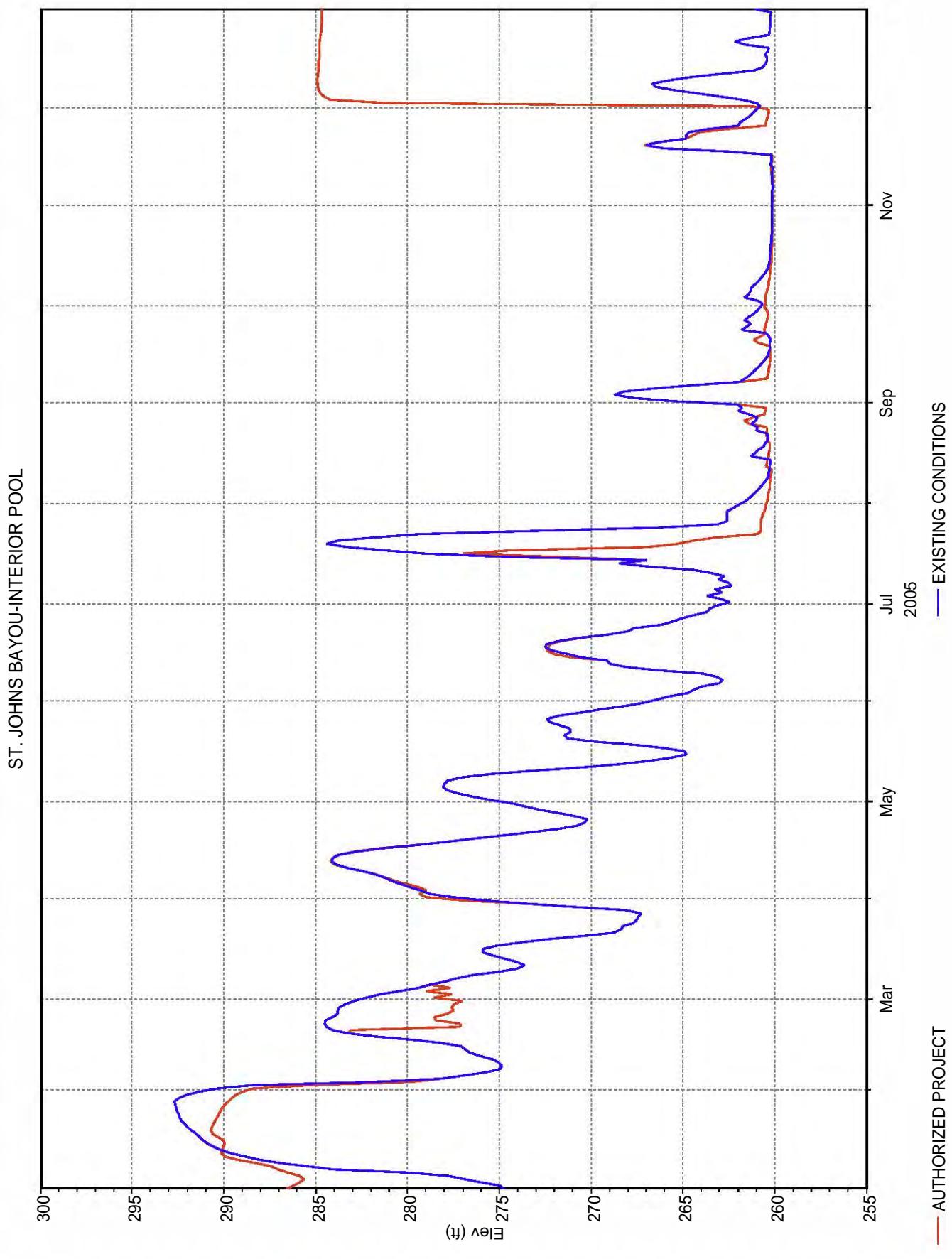


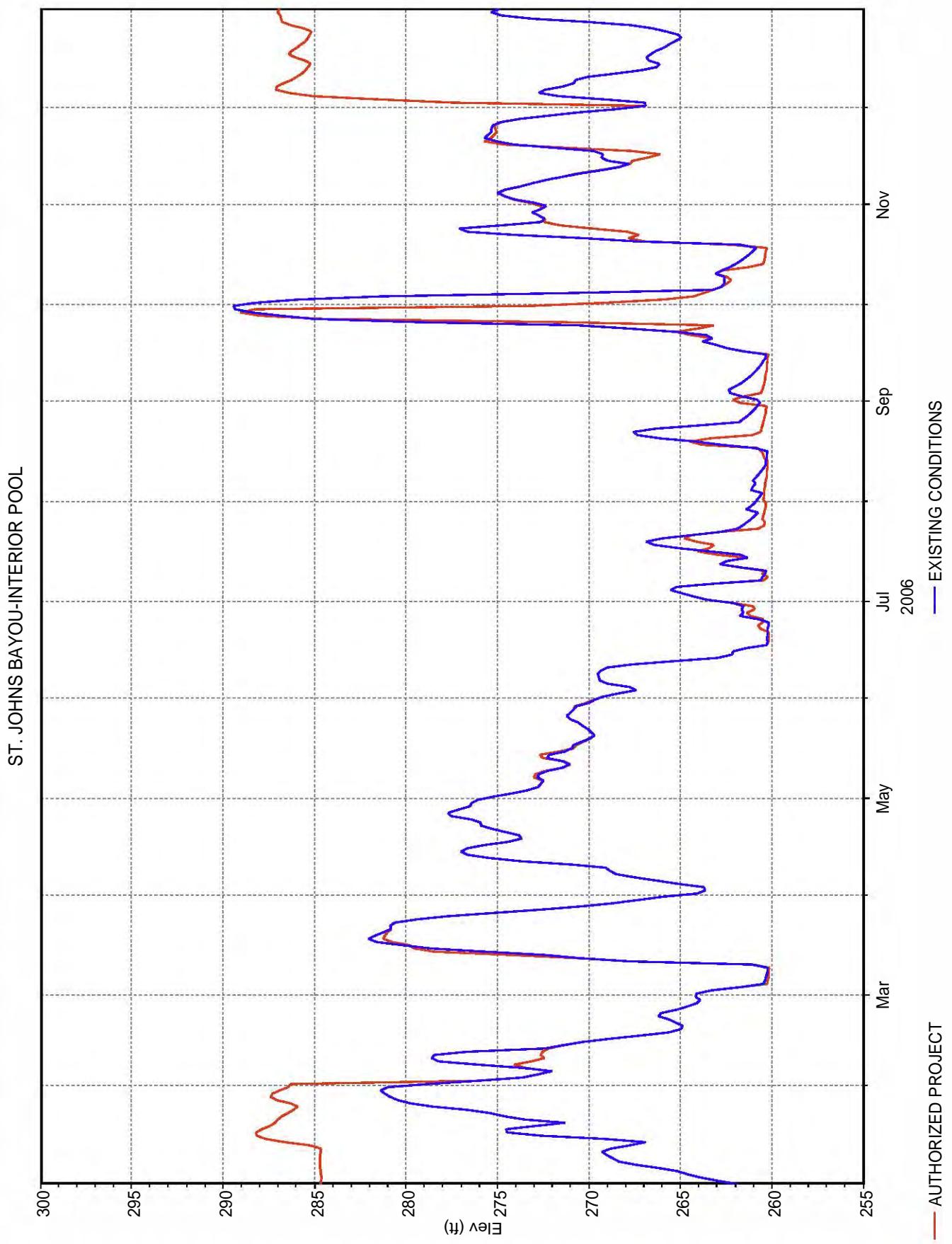


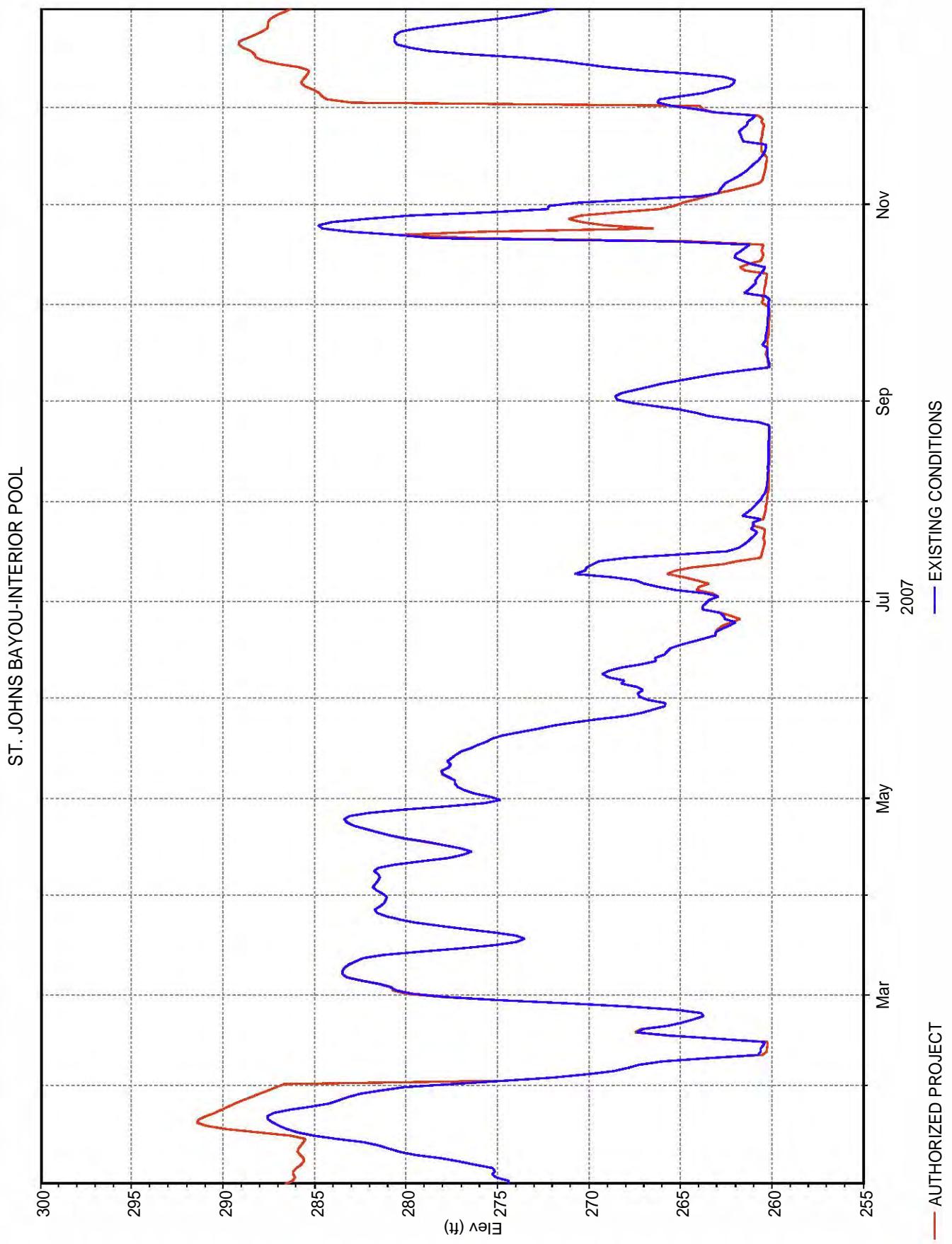


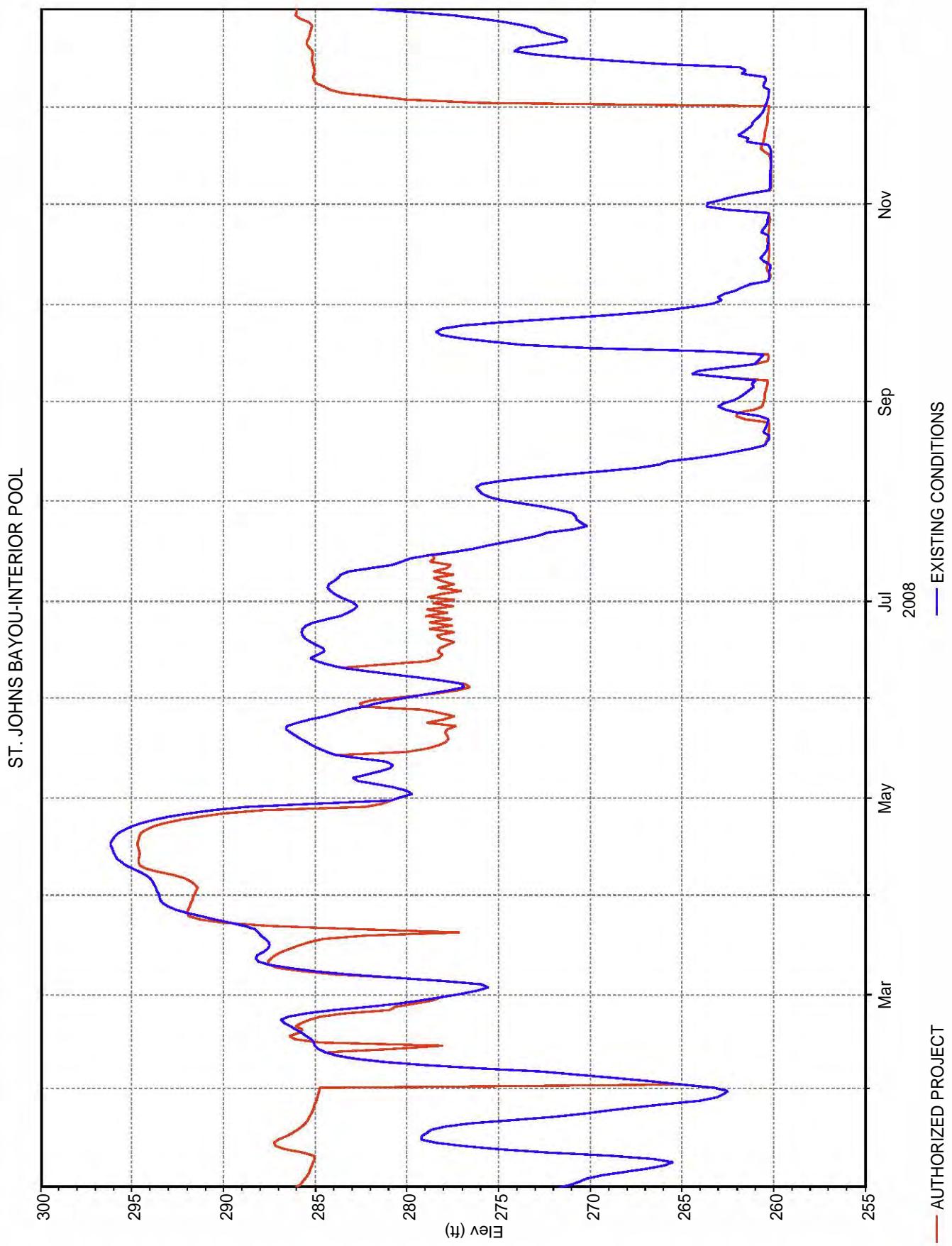


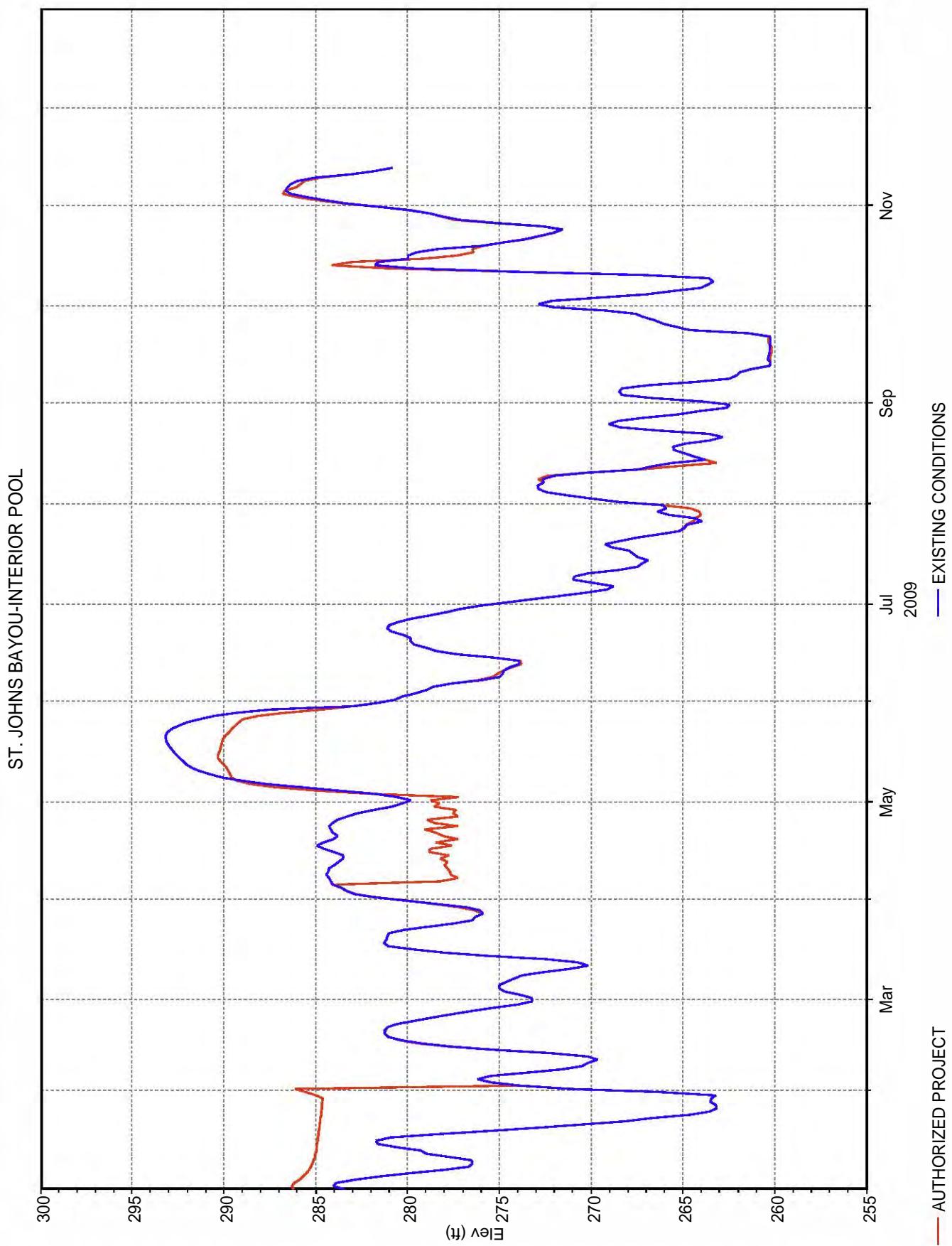


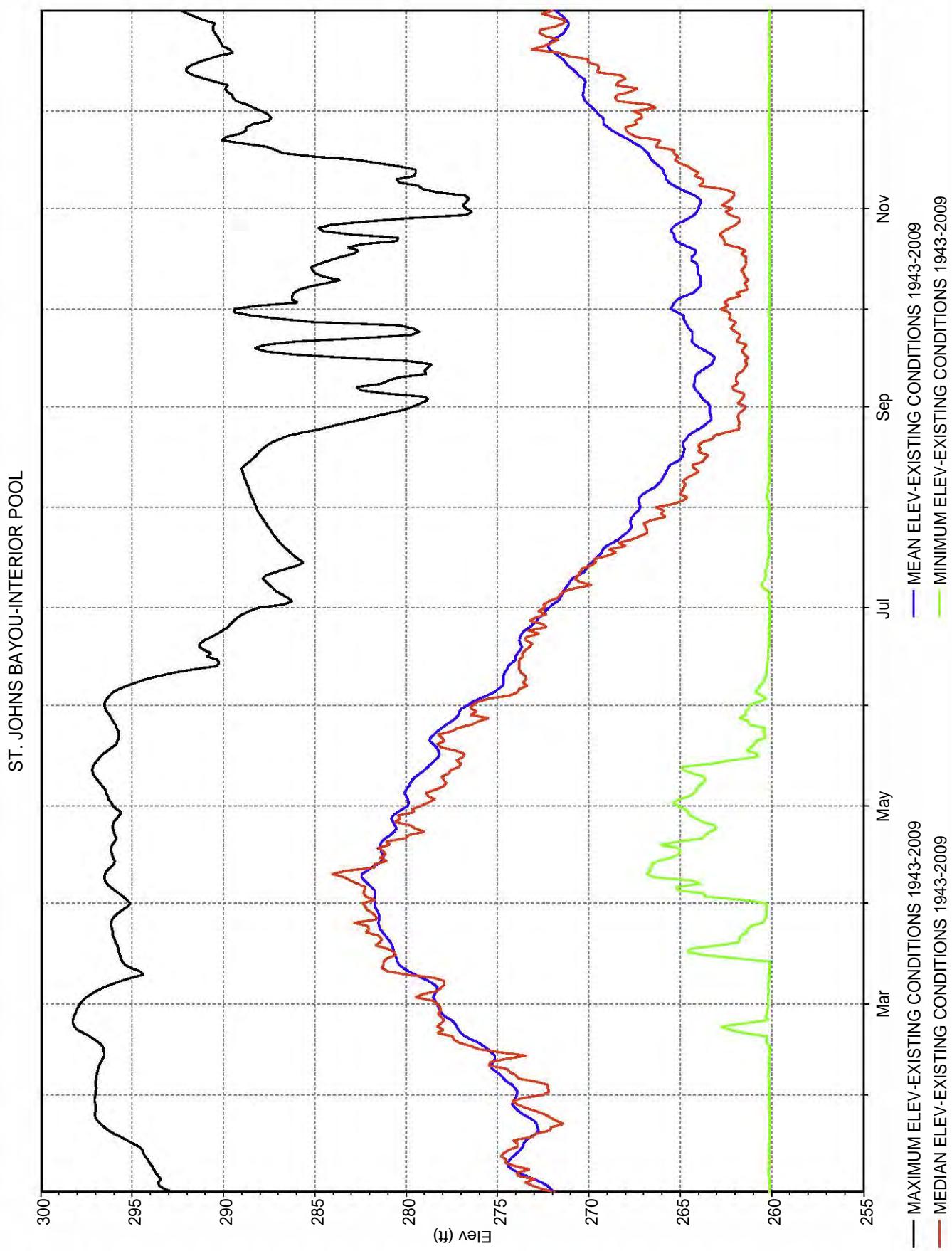


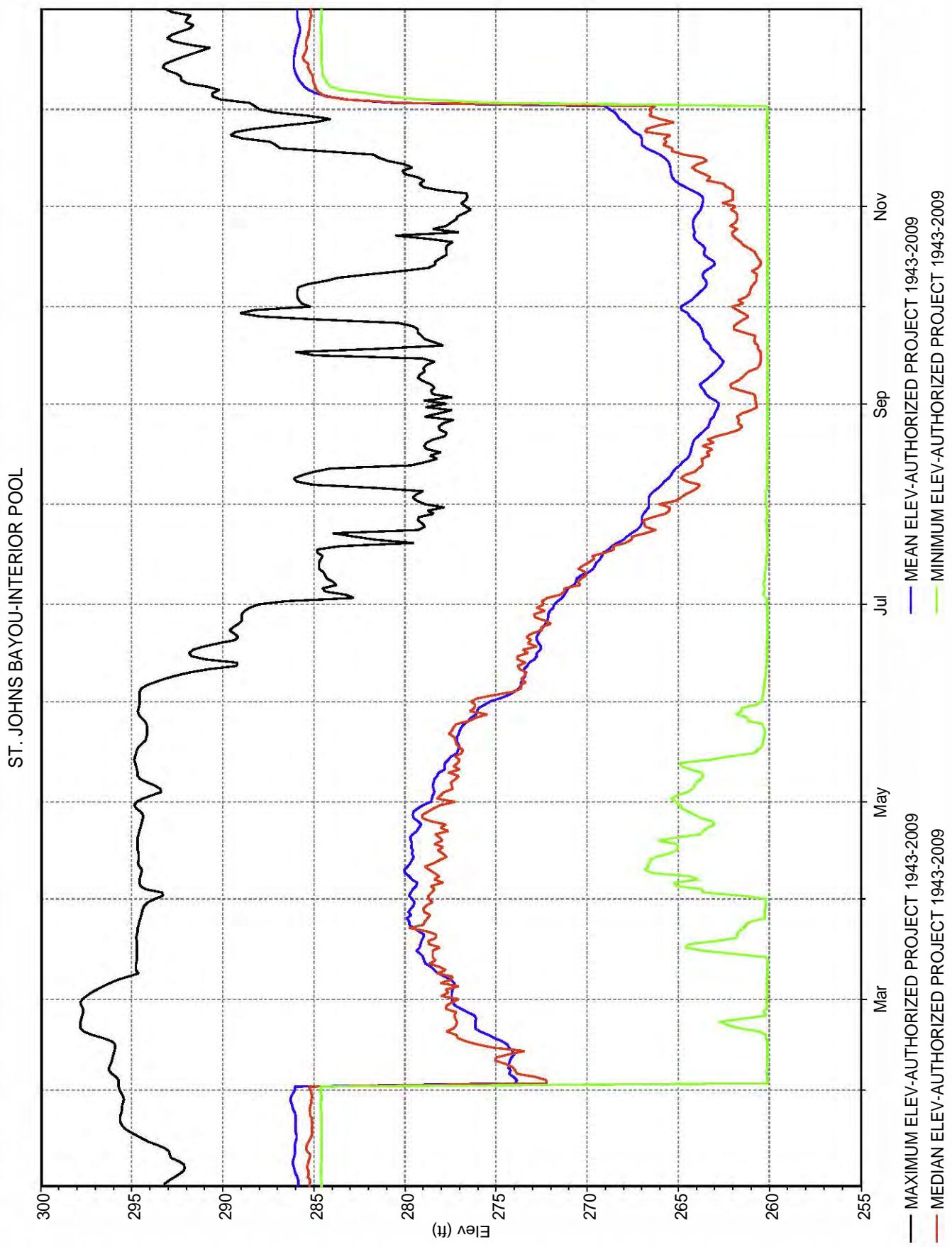




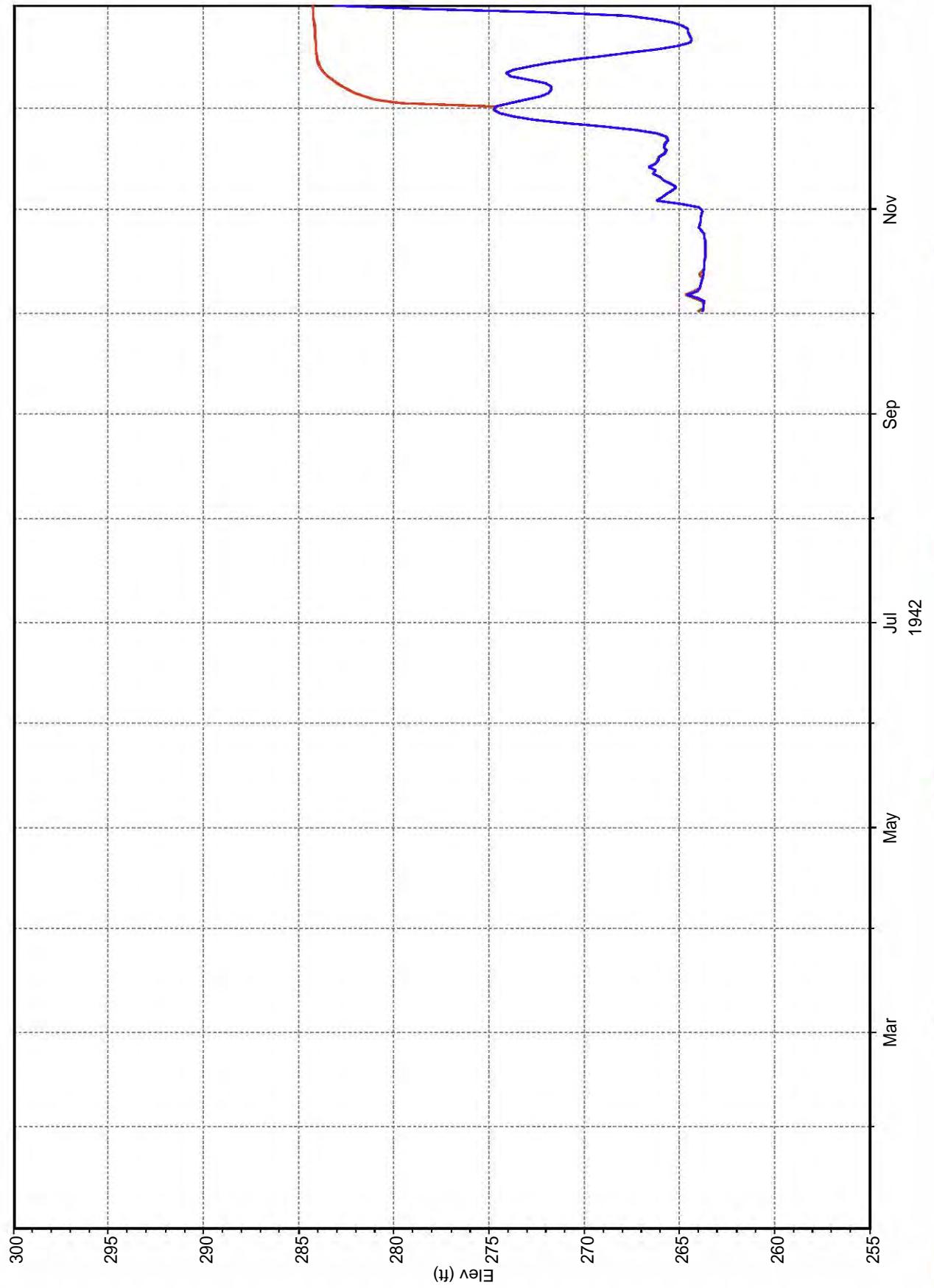




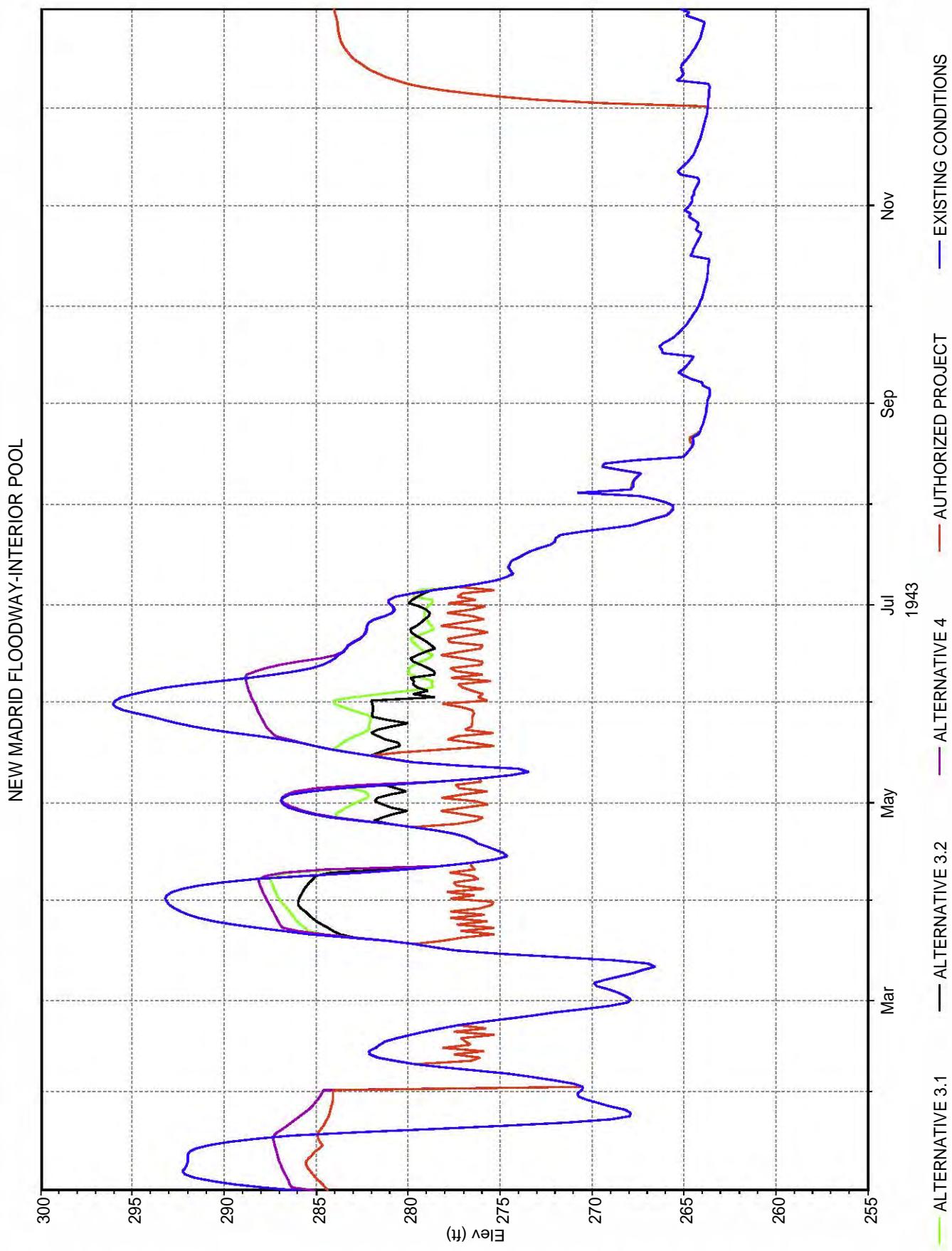




NEW MADRID FLOODWAY-INTERIOR POOL



C-93



NEW MADRID FLOODWAY-INTERIOR POOL

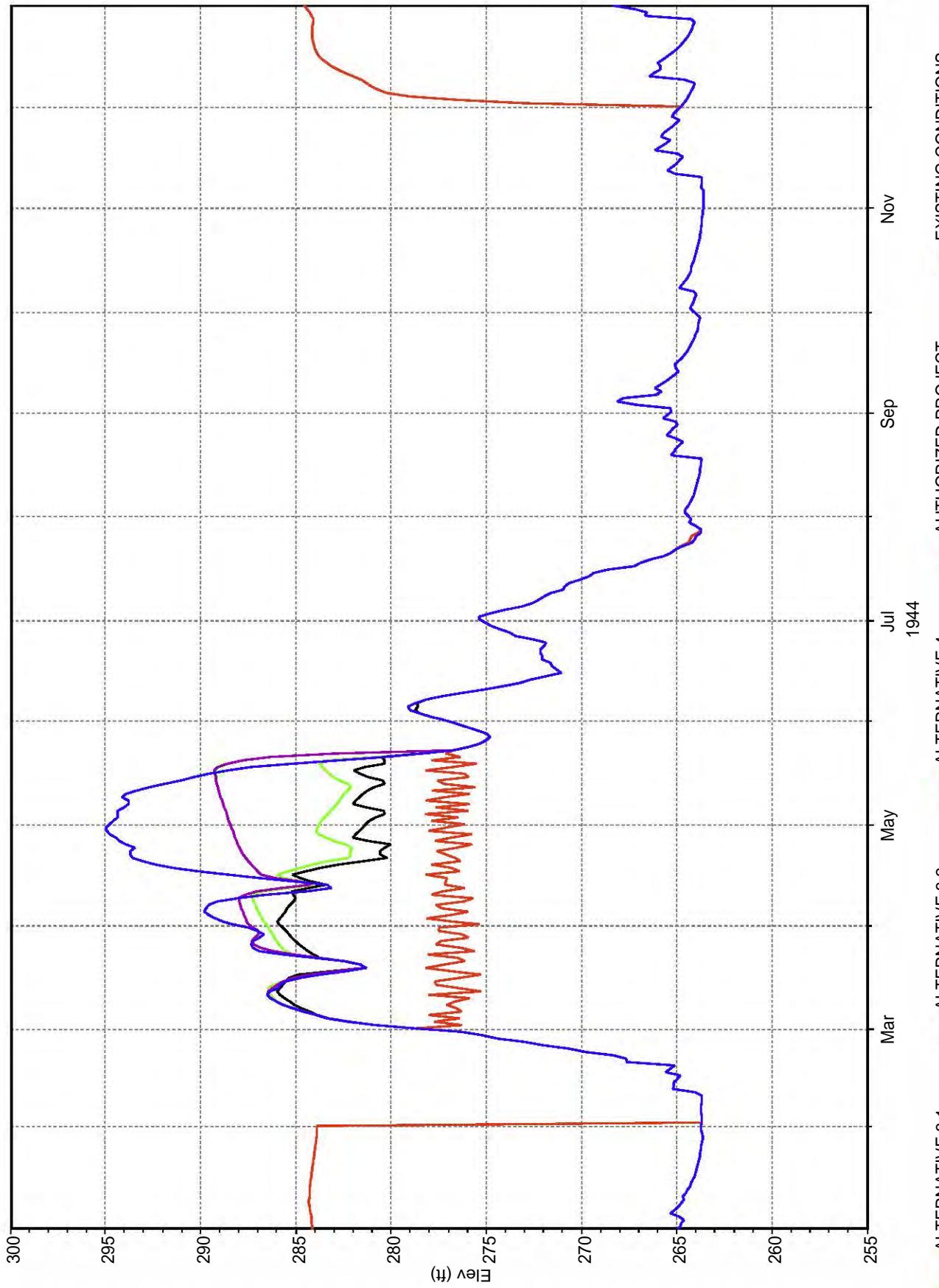
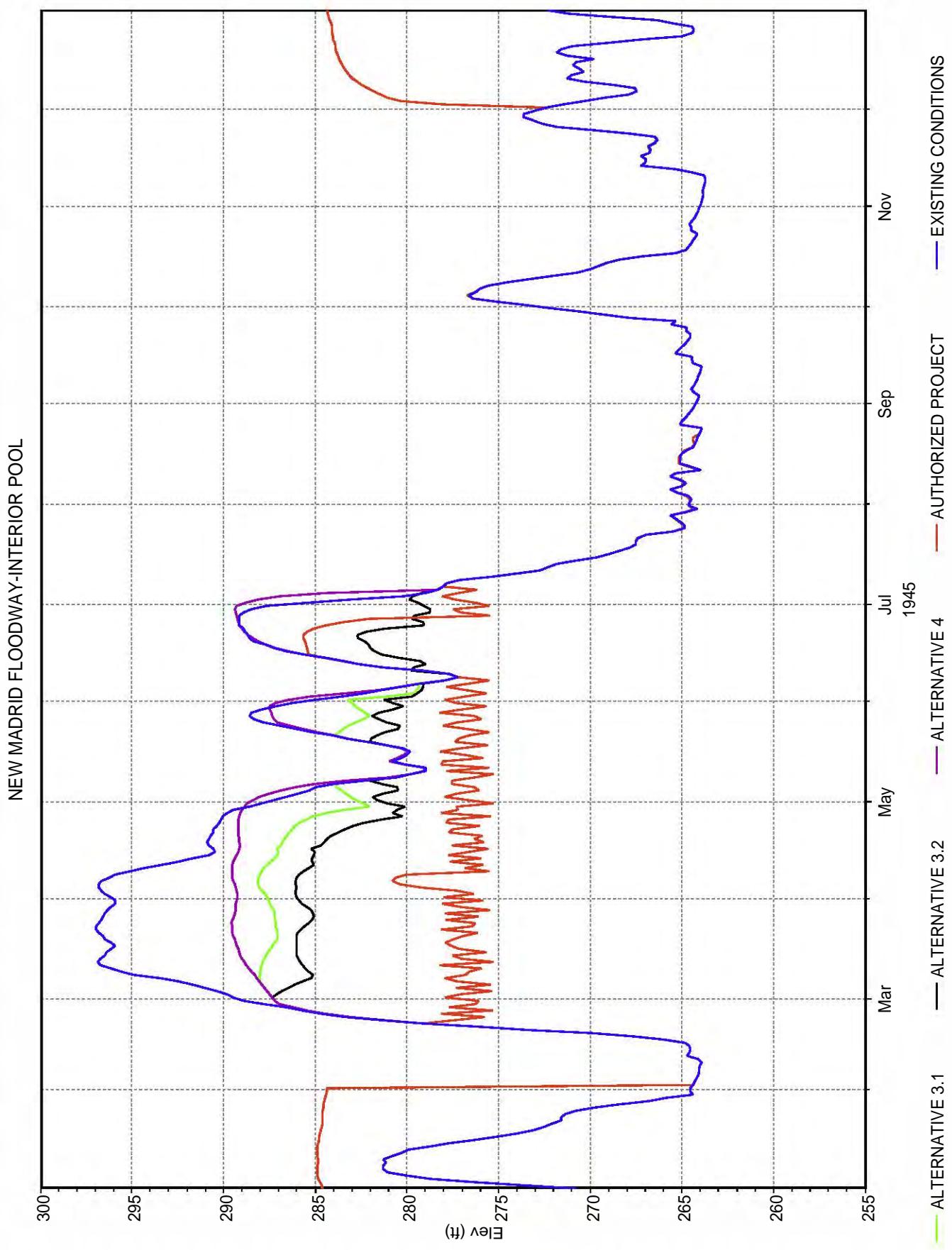
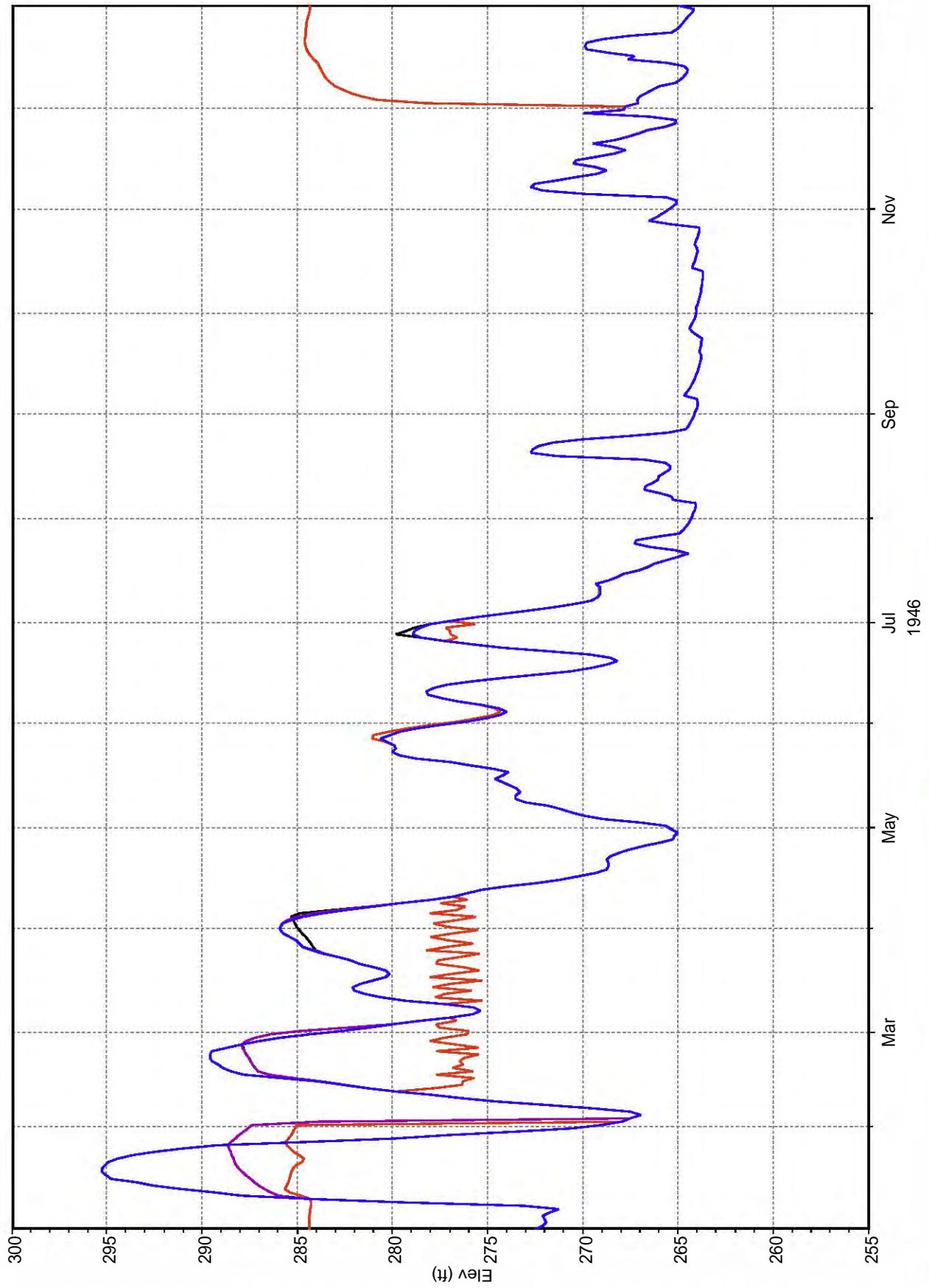
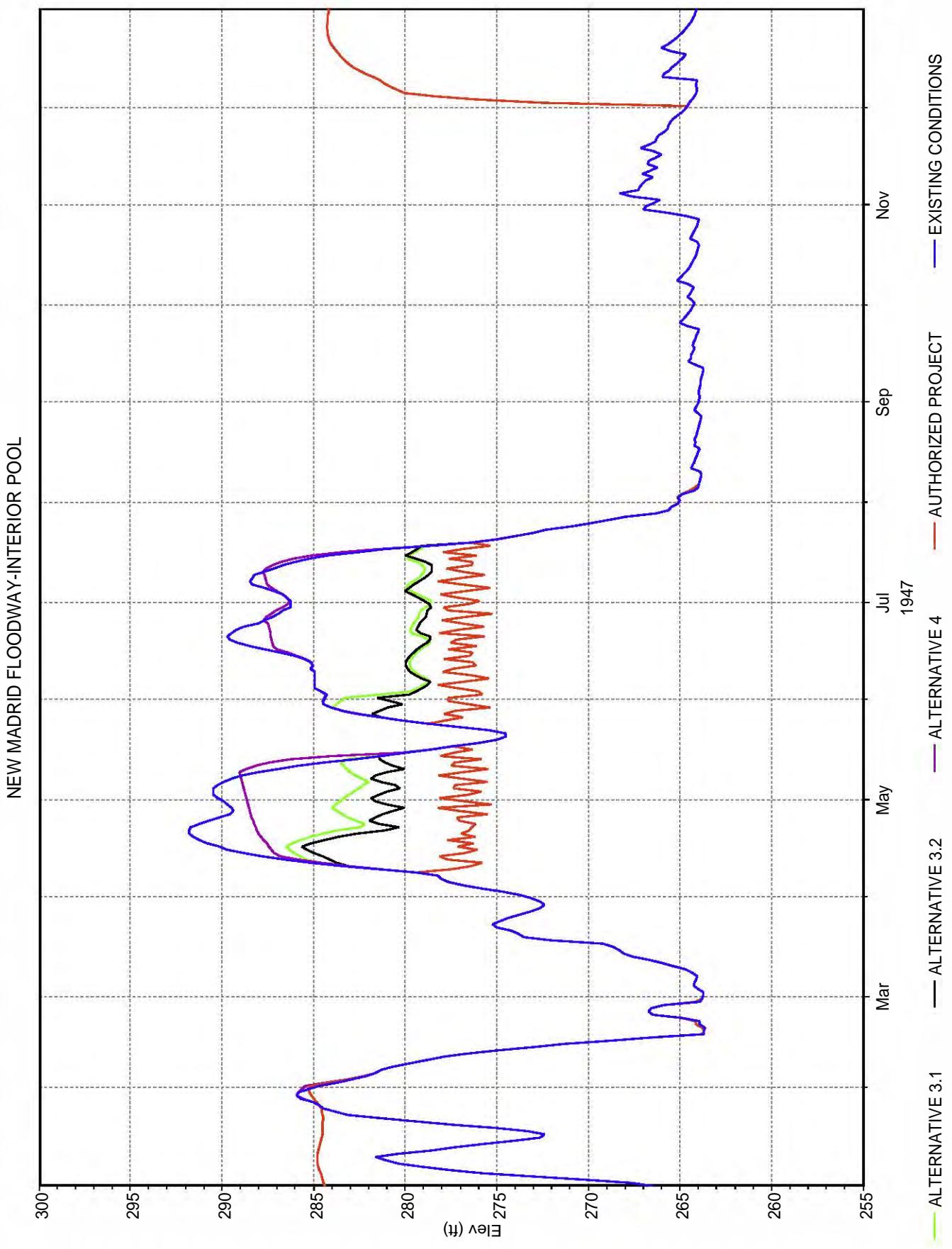


PLATE 75

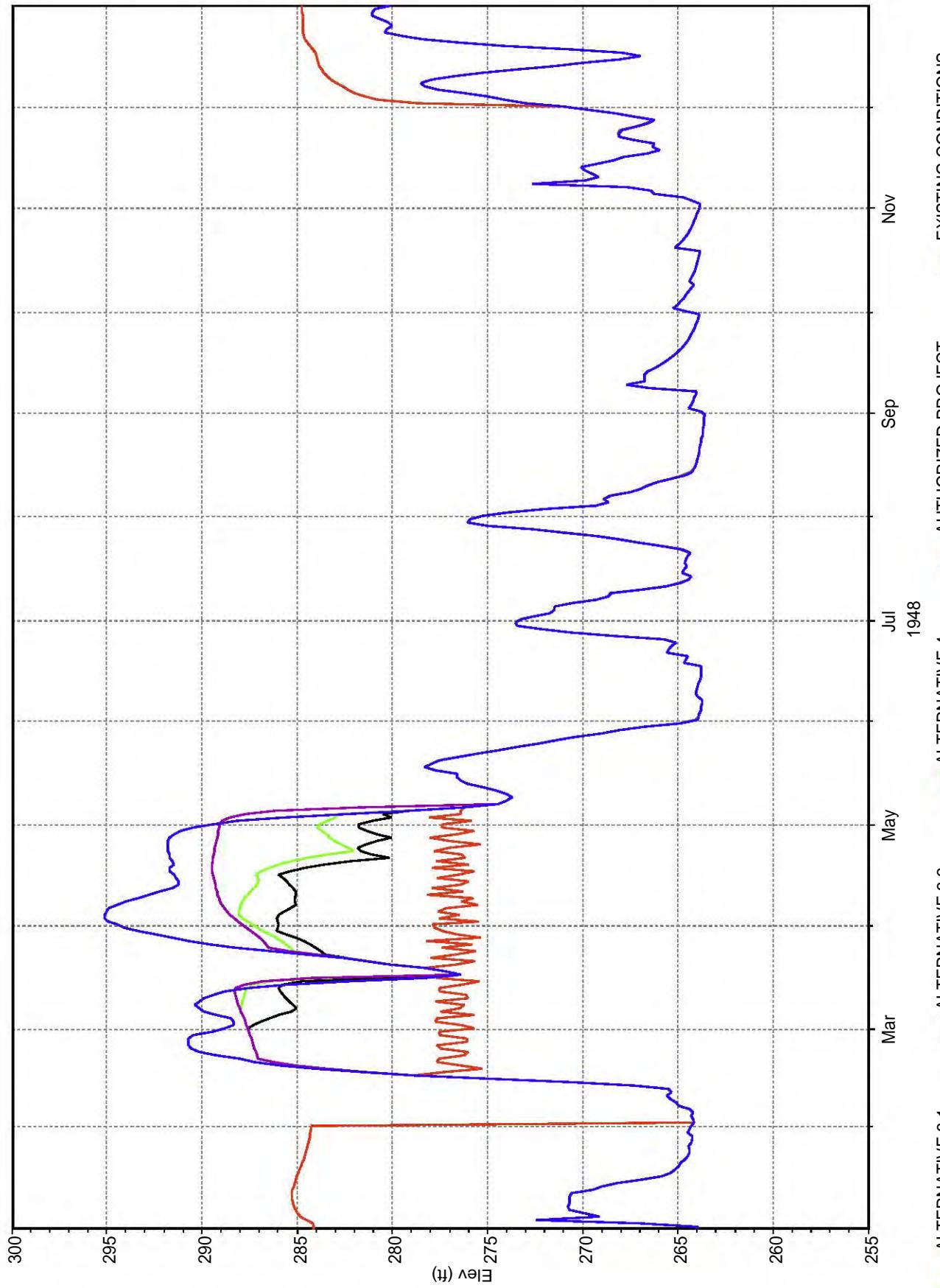


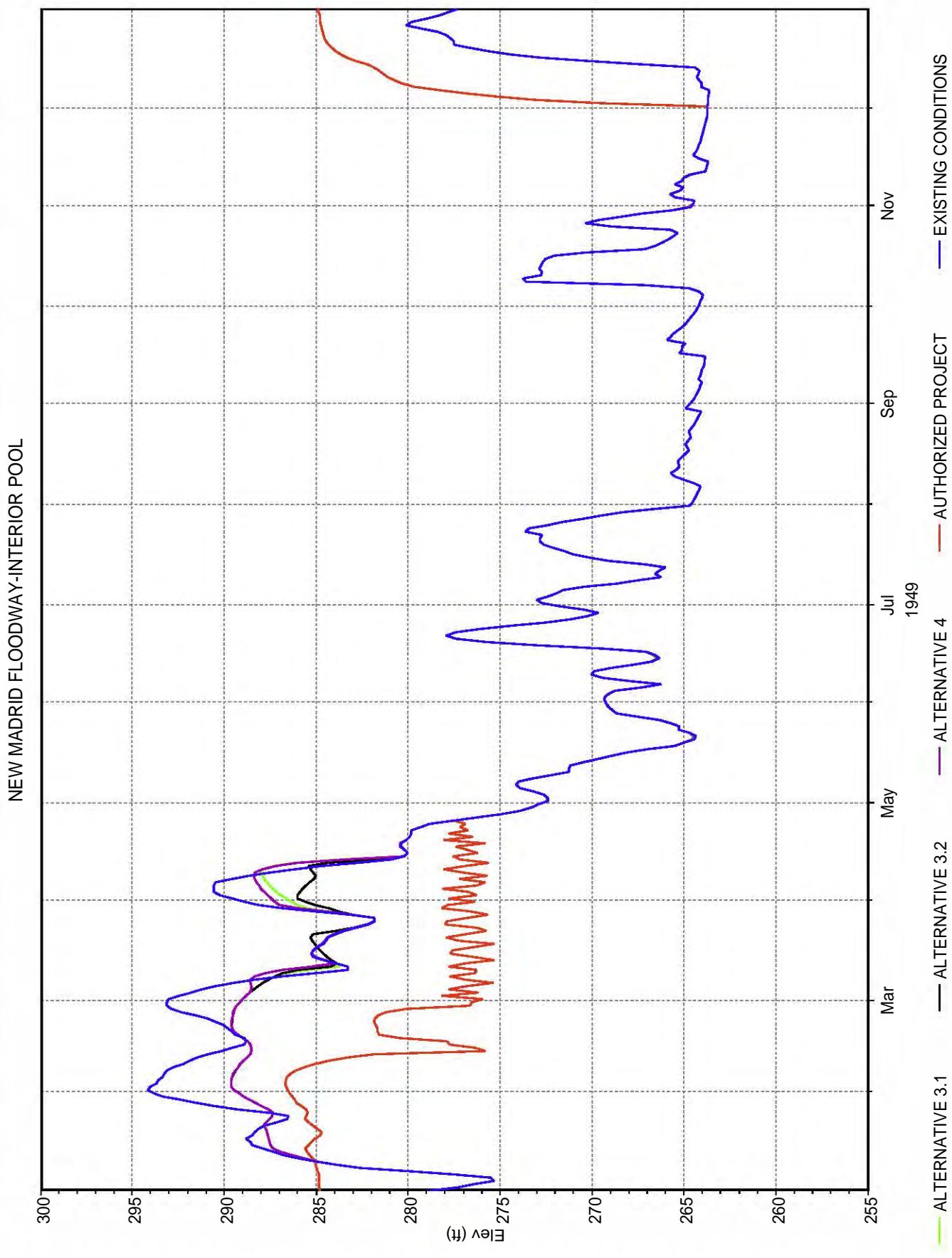
NEW MADRID FLOODWAY-INTERIOR POOL



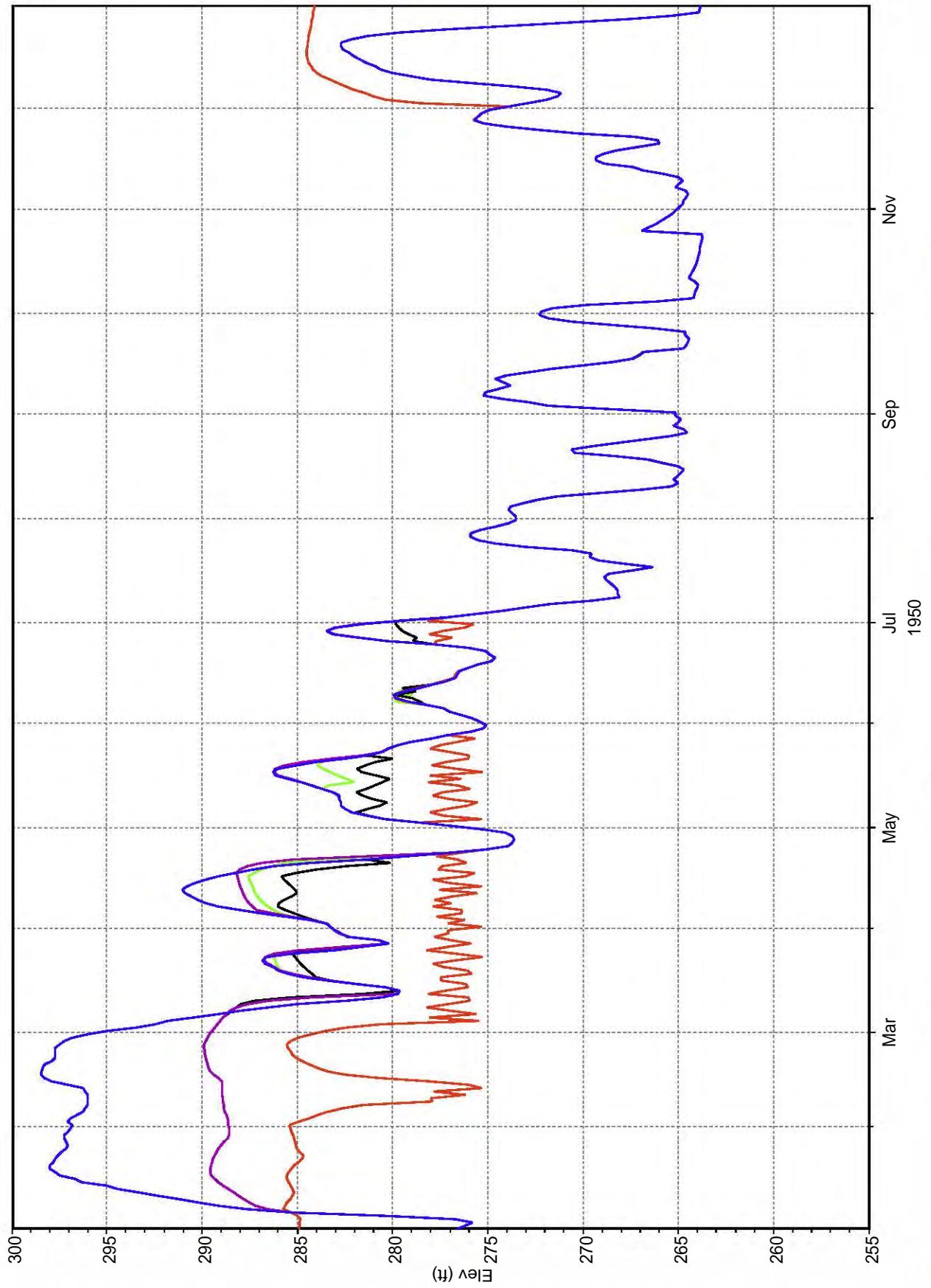


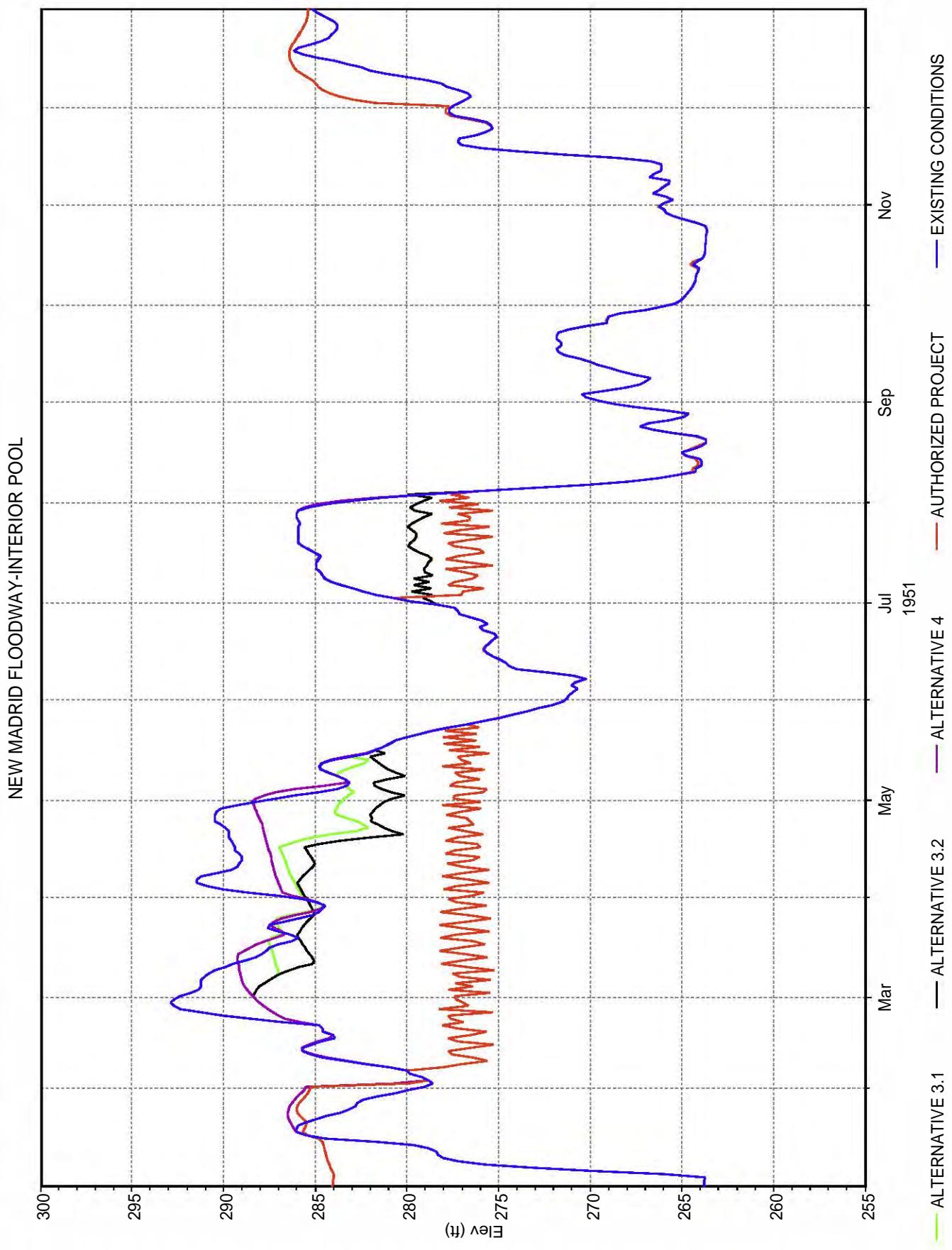
NEW MADRID FLOODWAY-INTERIOR POOL

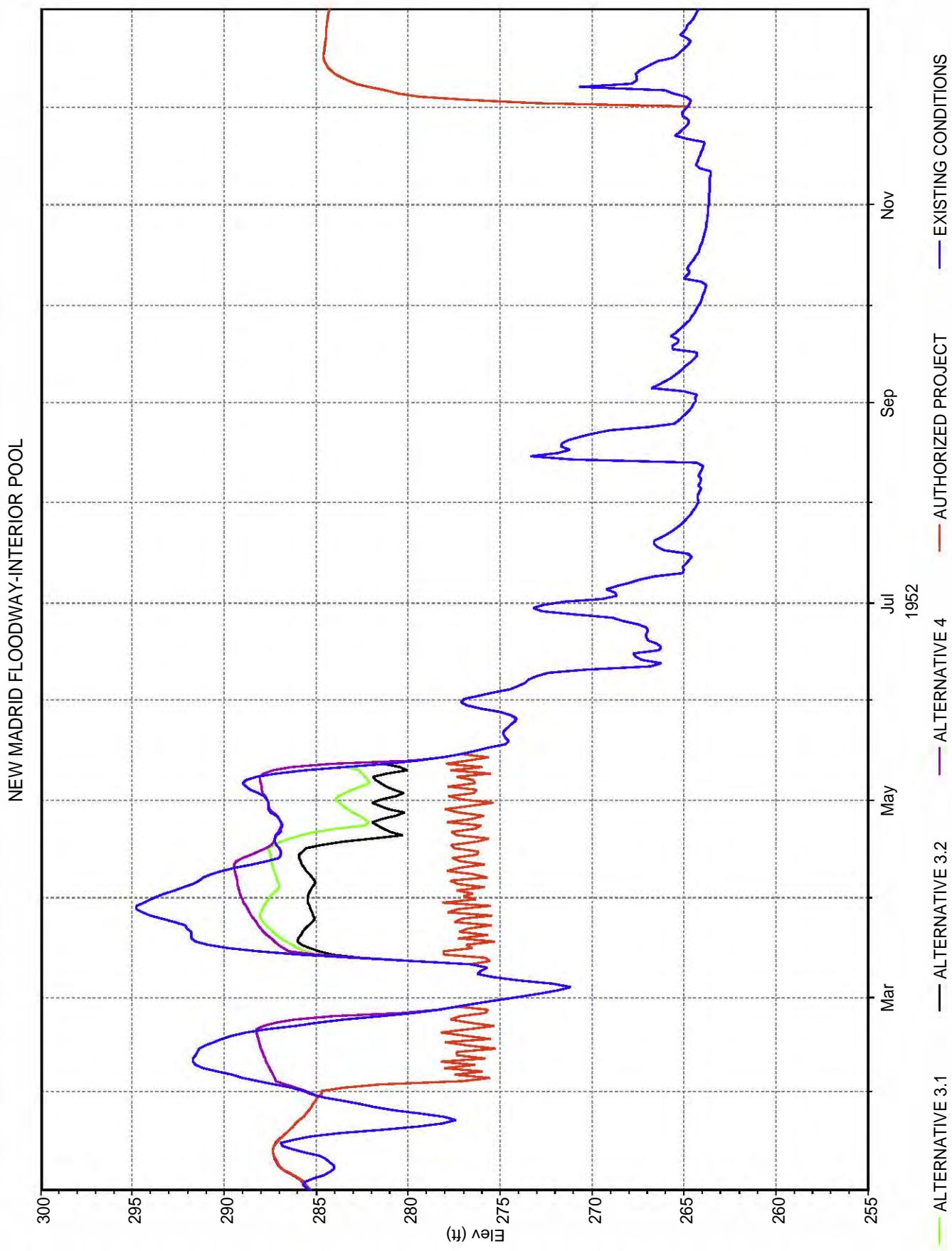




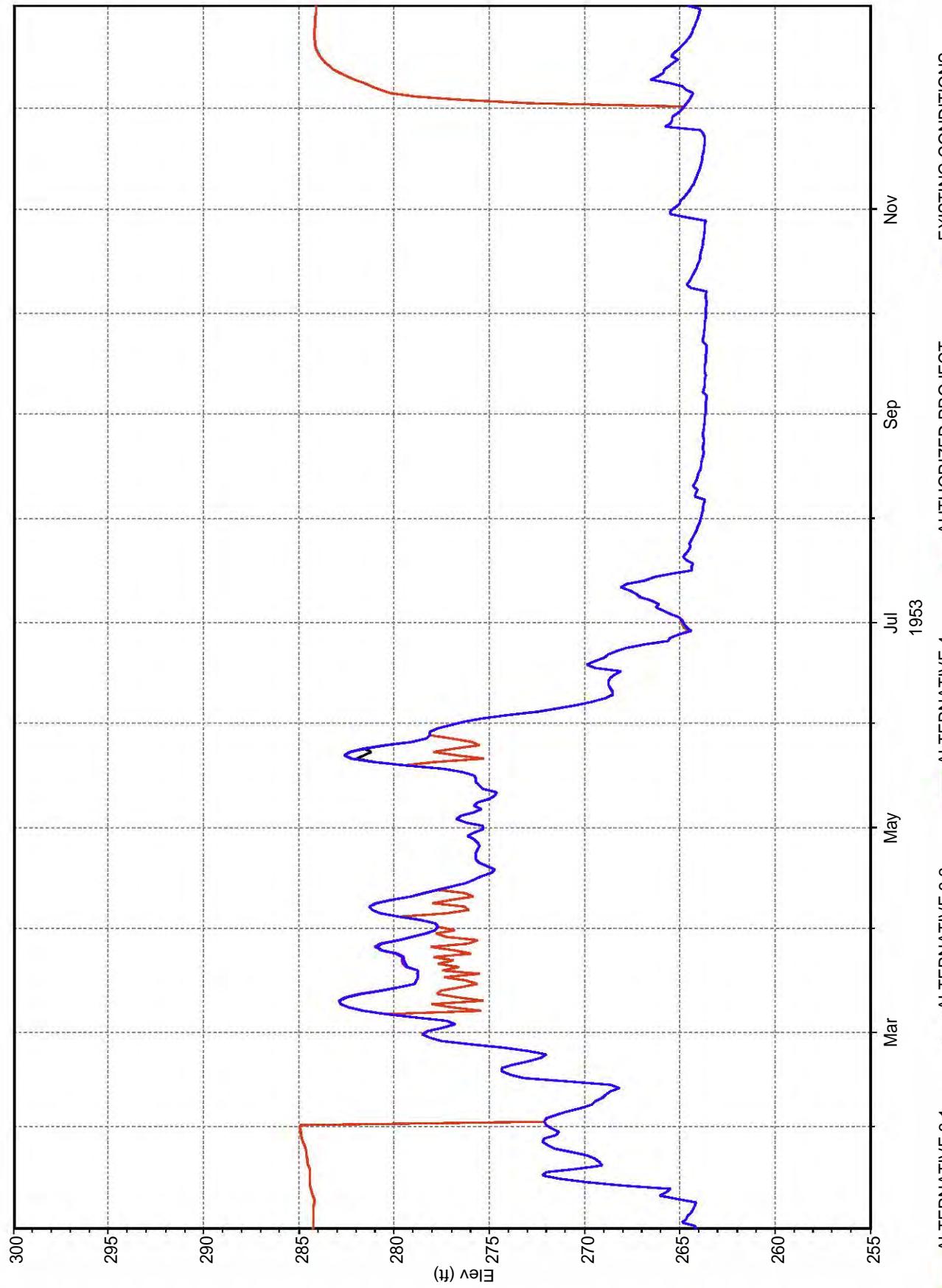
NEW MADRID FLOODWAY-INTERIOR POOL



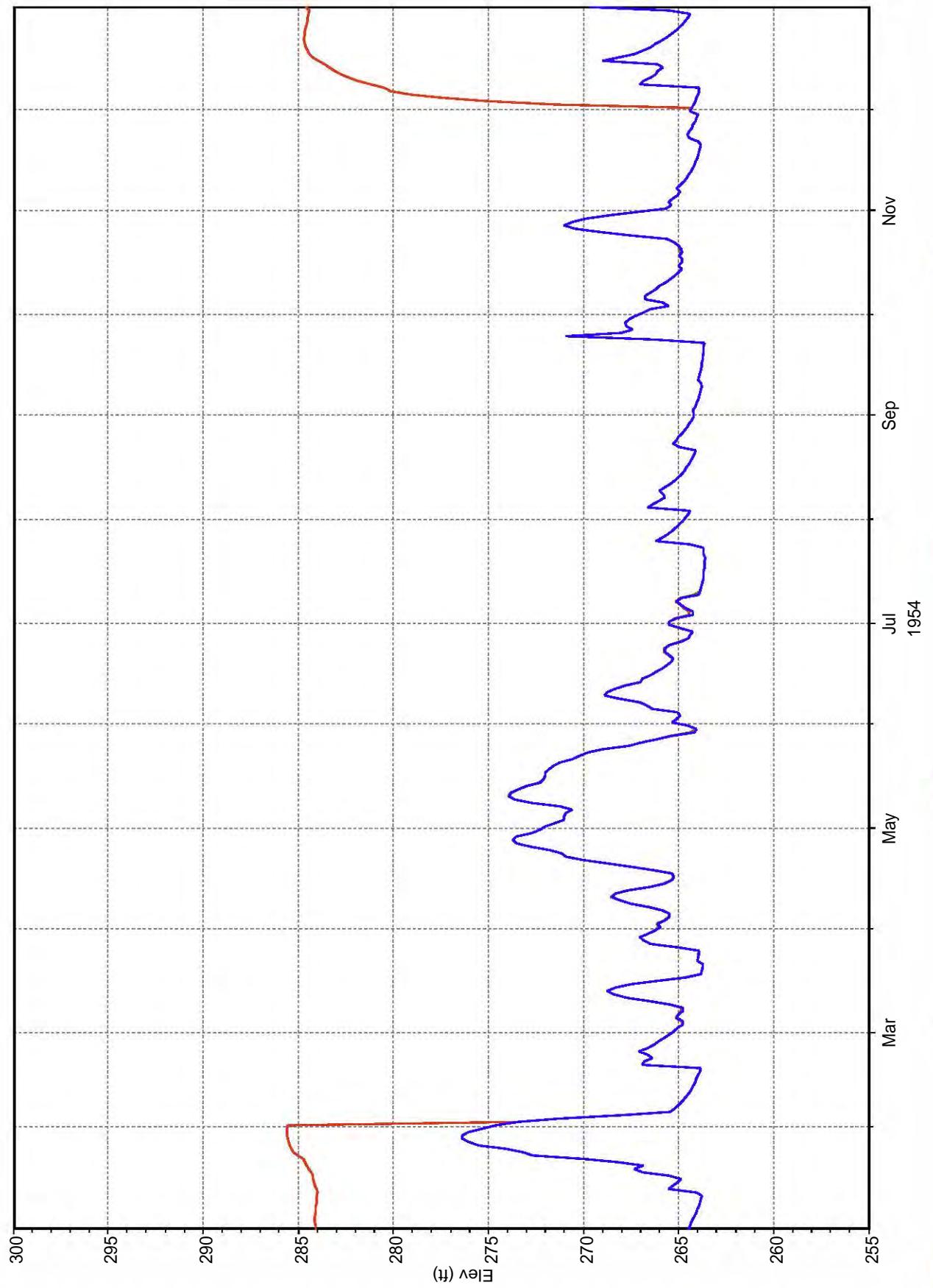




NEW MADRID FLOODWAY-INTERIOR POOL

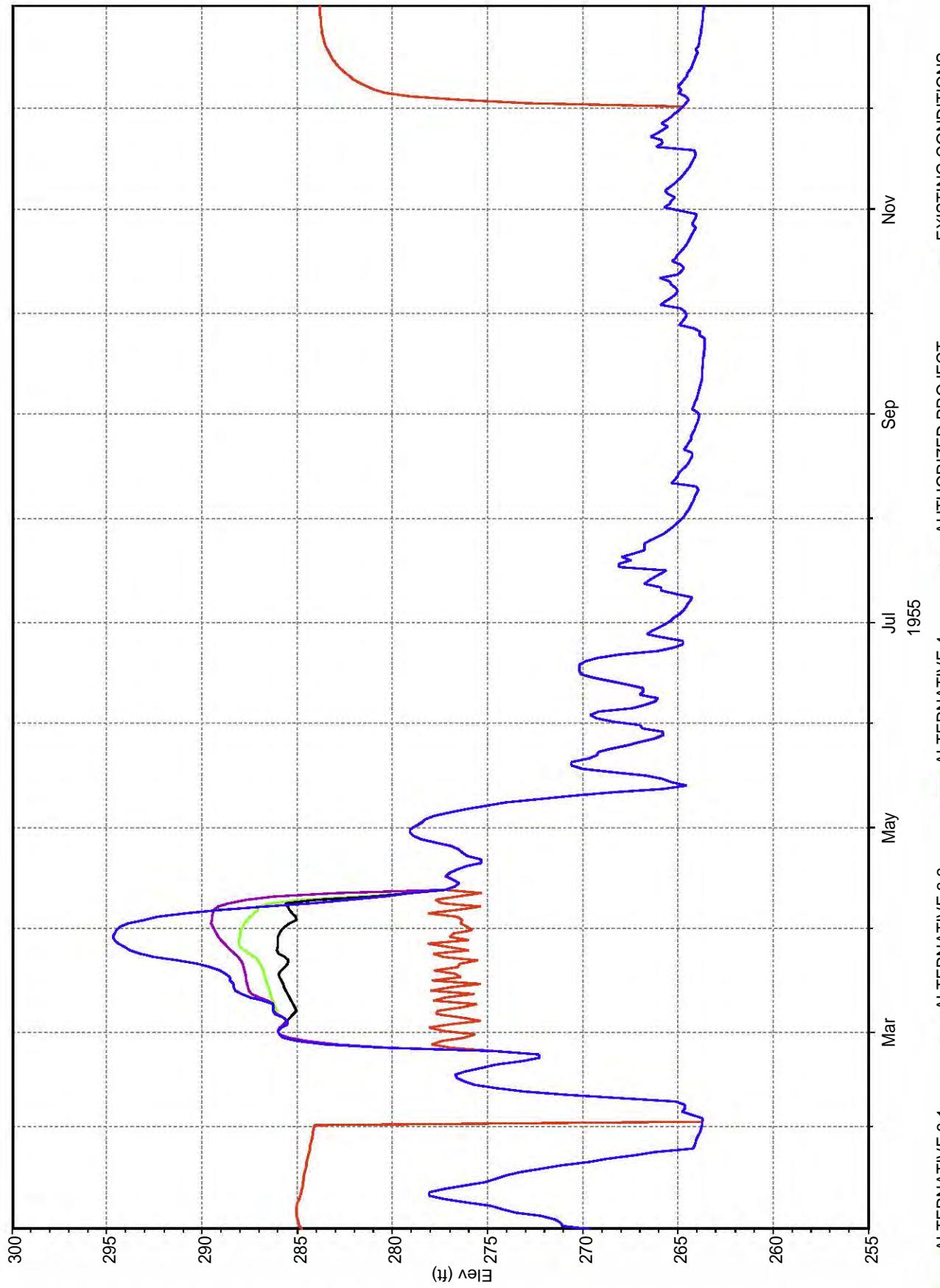


NEW MADRID FLOODWAY-INTERIOR POOL



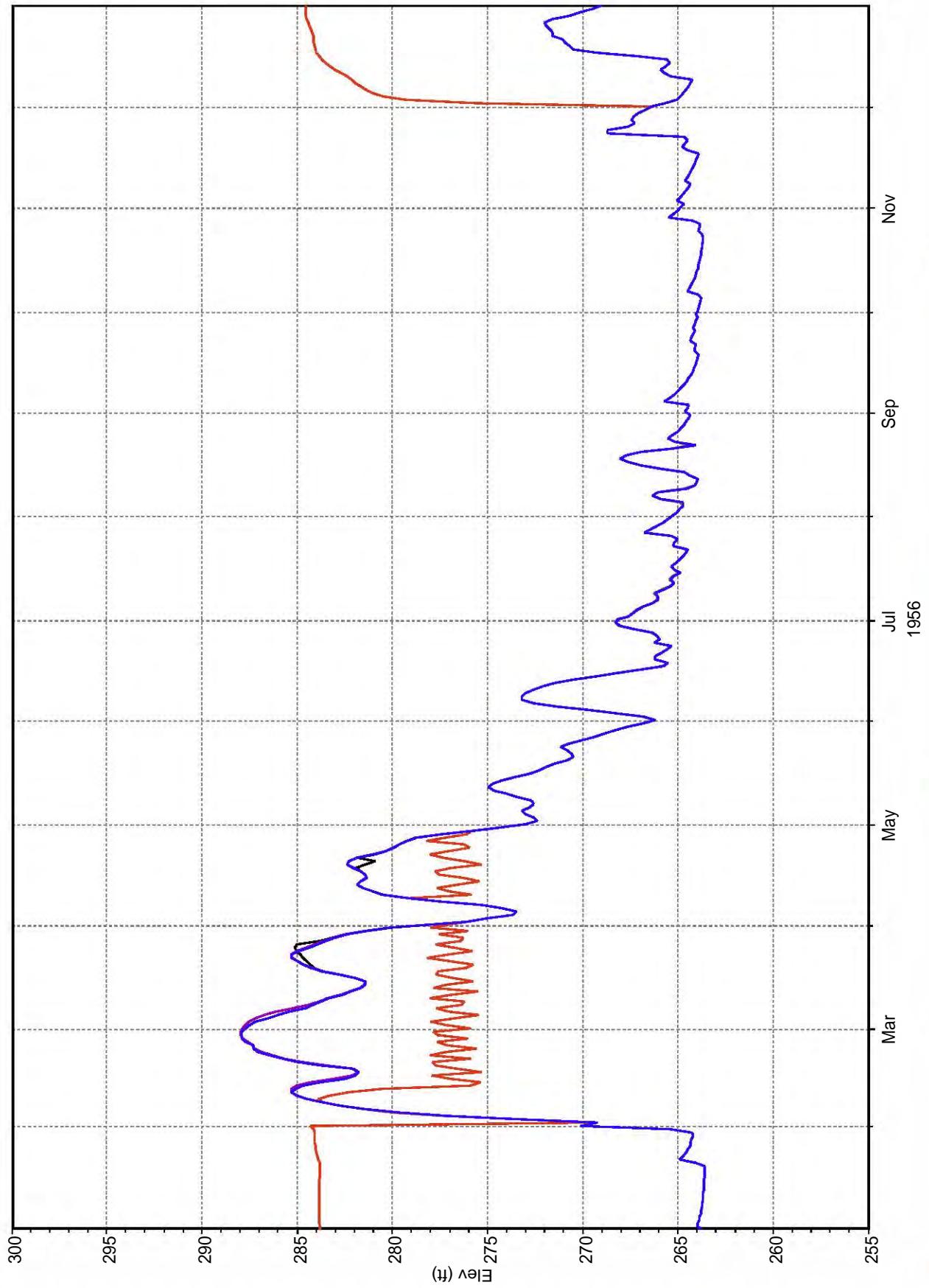
C-105

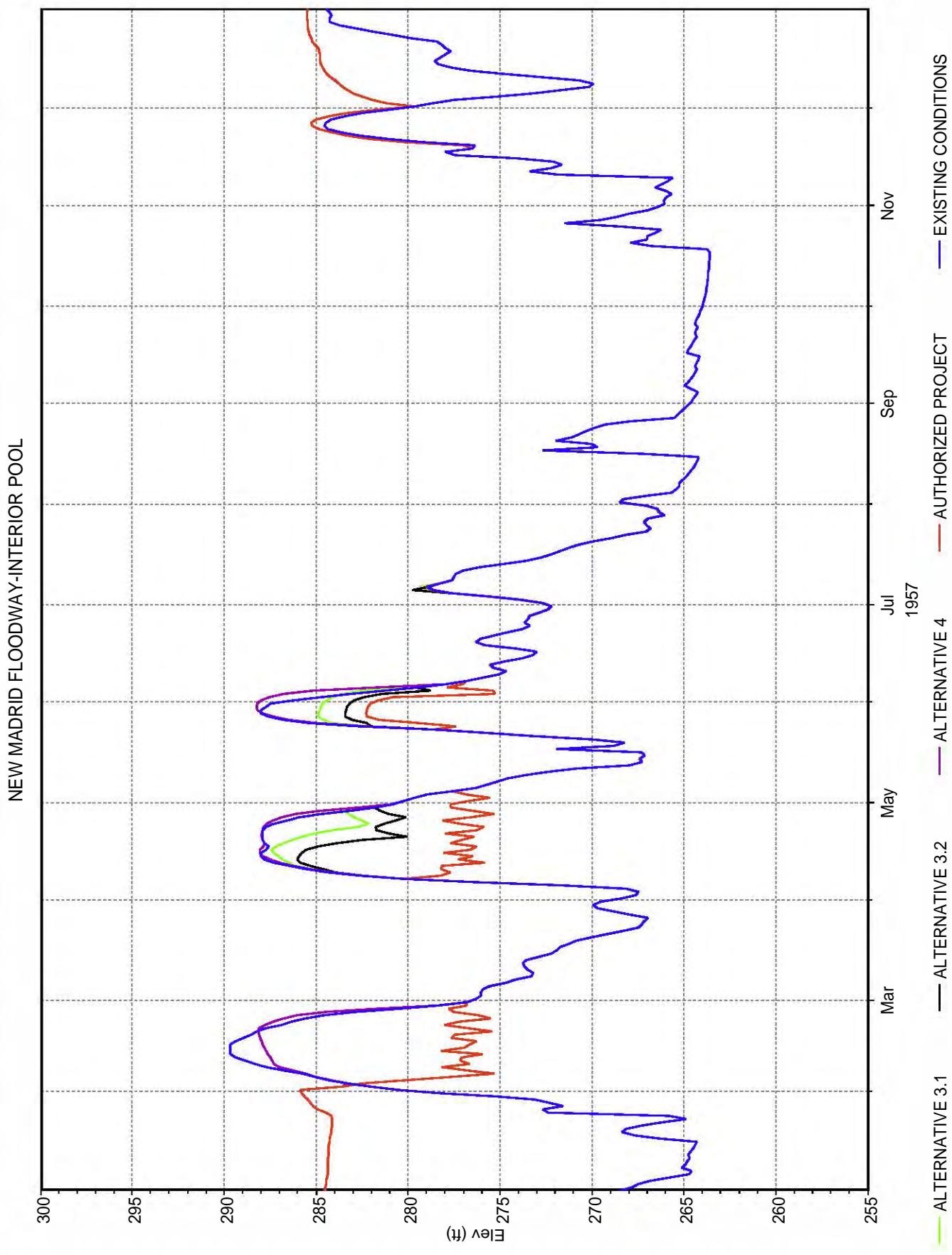
NEW MADRID FLOODWAY-INTERIOR POOL

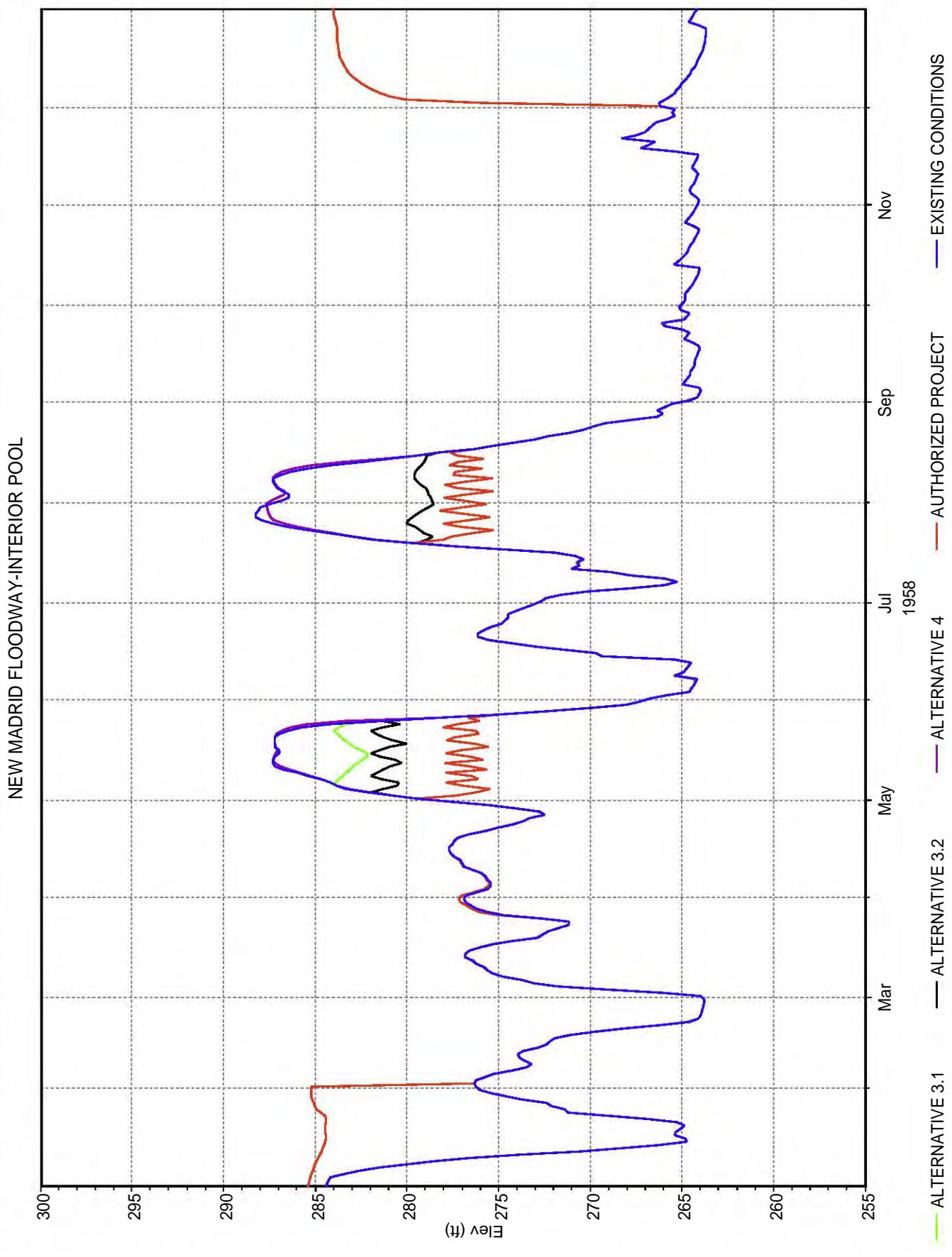


C-106

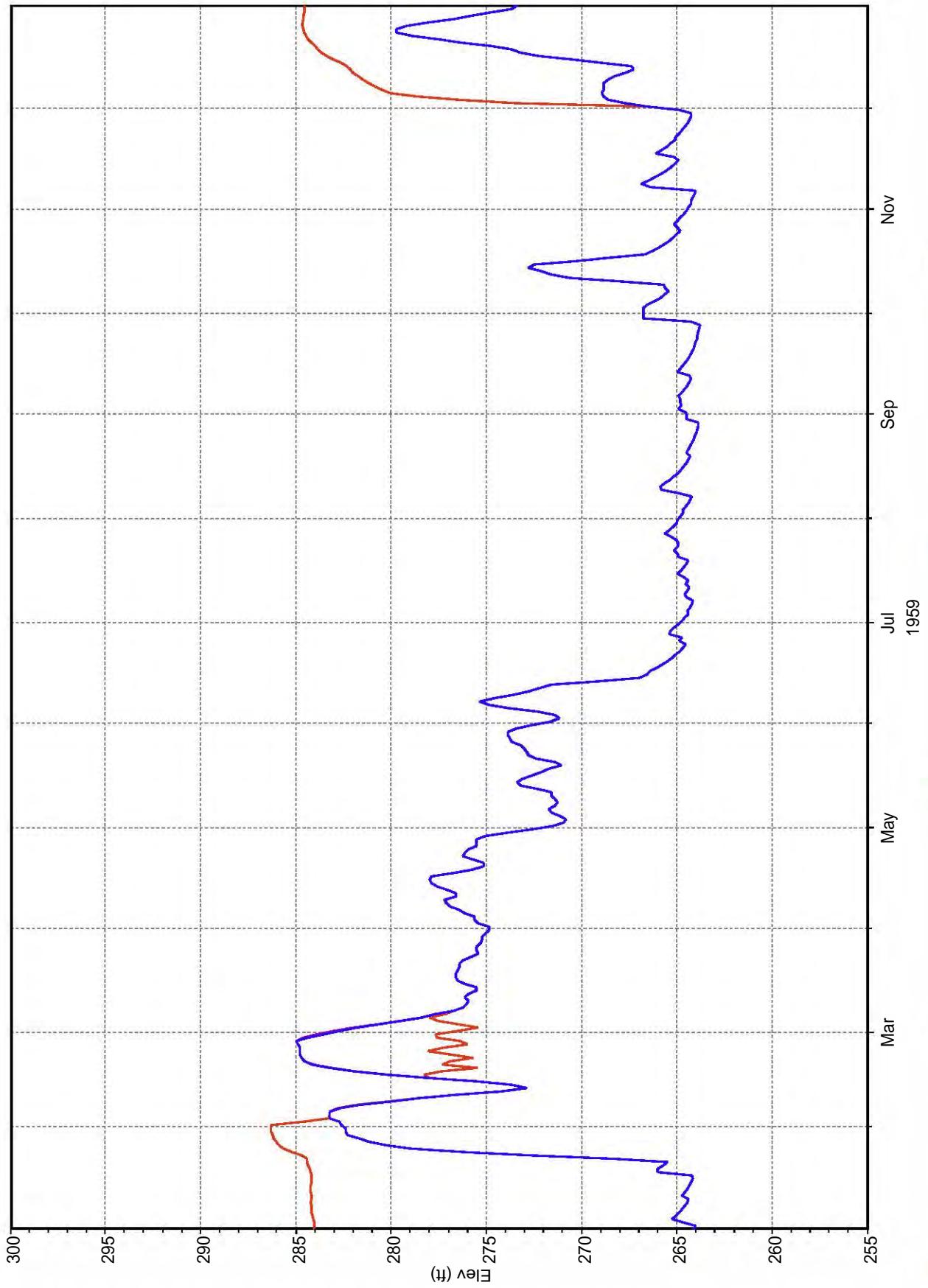
NEW MADRID FLOODWAY-INTERIOR POOL







NEW MADRID FLOODWAY-INTERIOR POOL

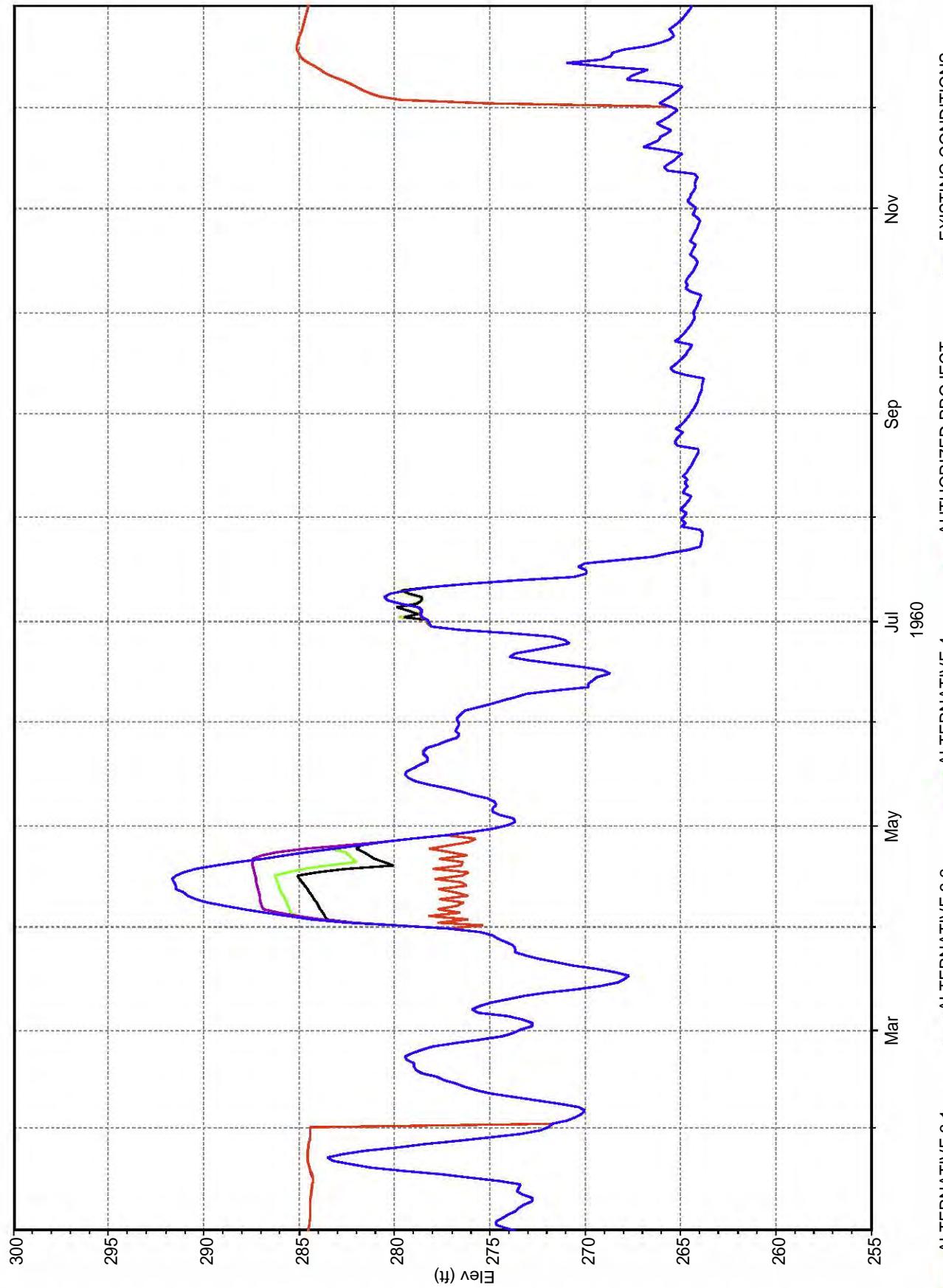


C-110

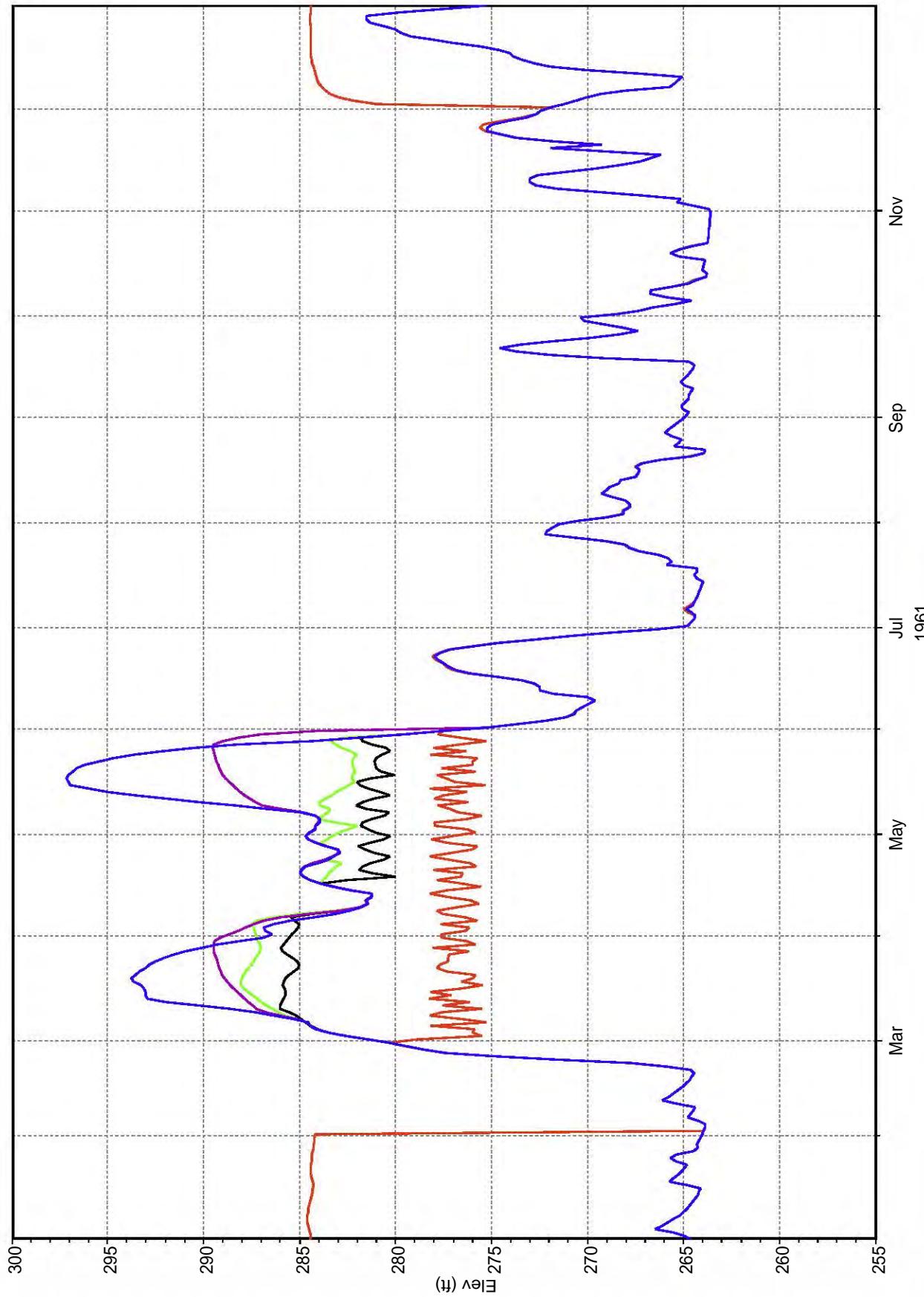
— ALTERNATIVE 3.1 — ALTERNATIVE 3.2 — ALTERNATIVE 4 — AUTHORIZED PROJECT — EXISTING CONDITIONS

PLATE 90

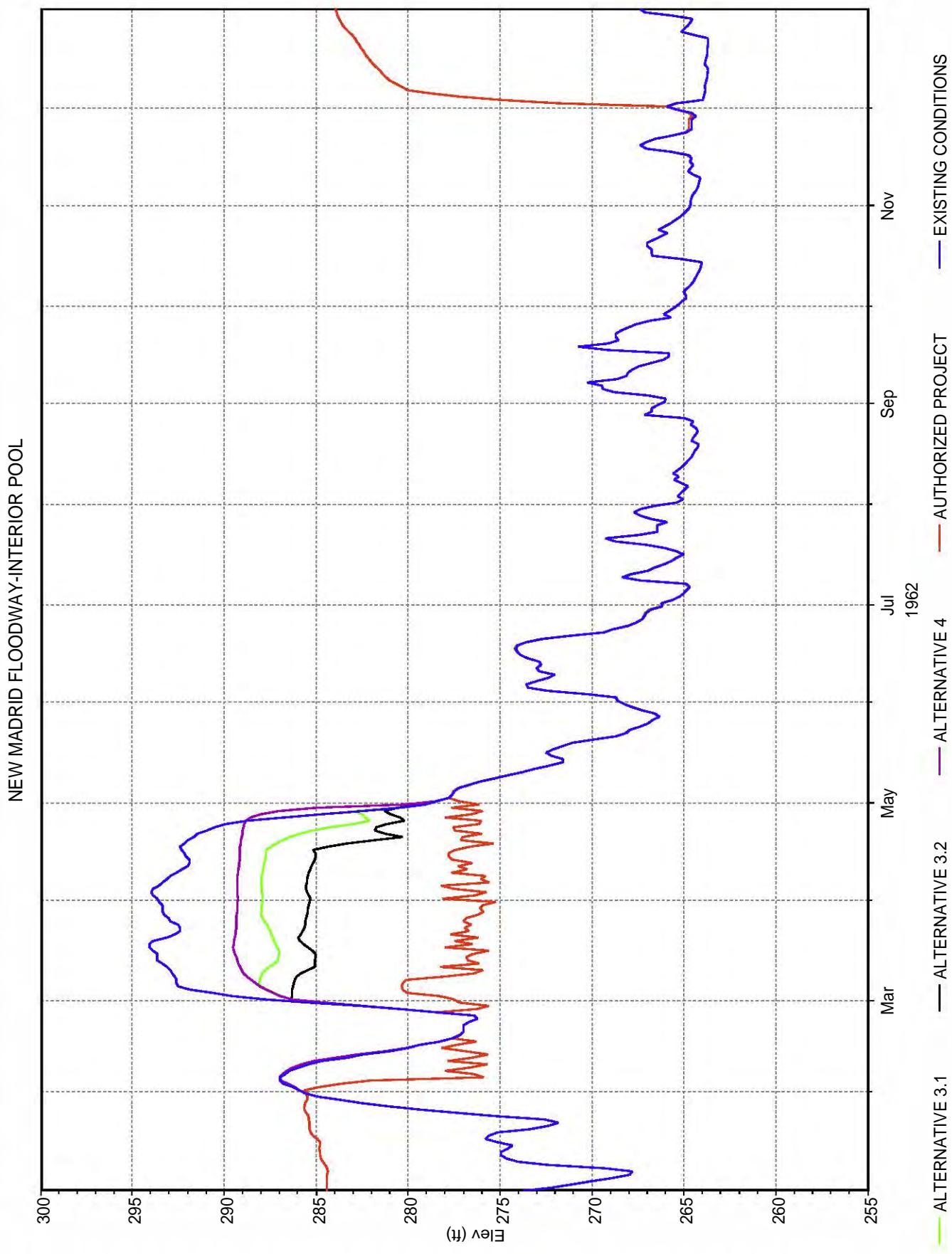
NEW MADRID FLOODWAY-INTERIOR POOL

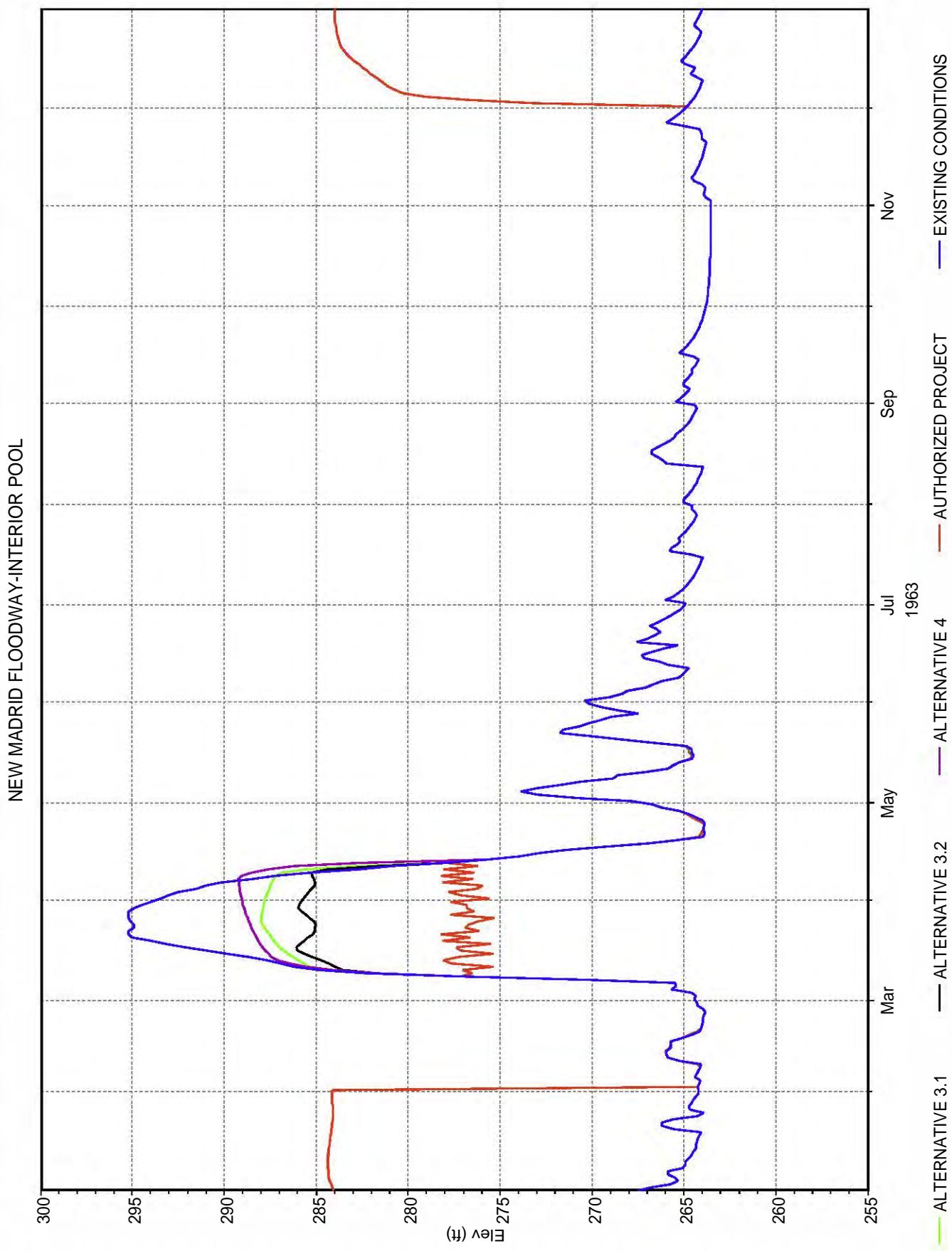


NEW MADRID FLOODWAY-INTERIOR POOL

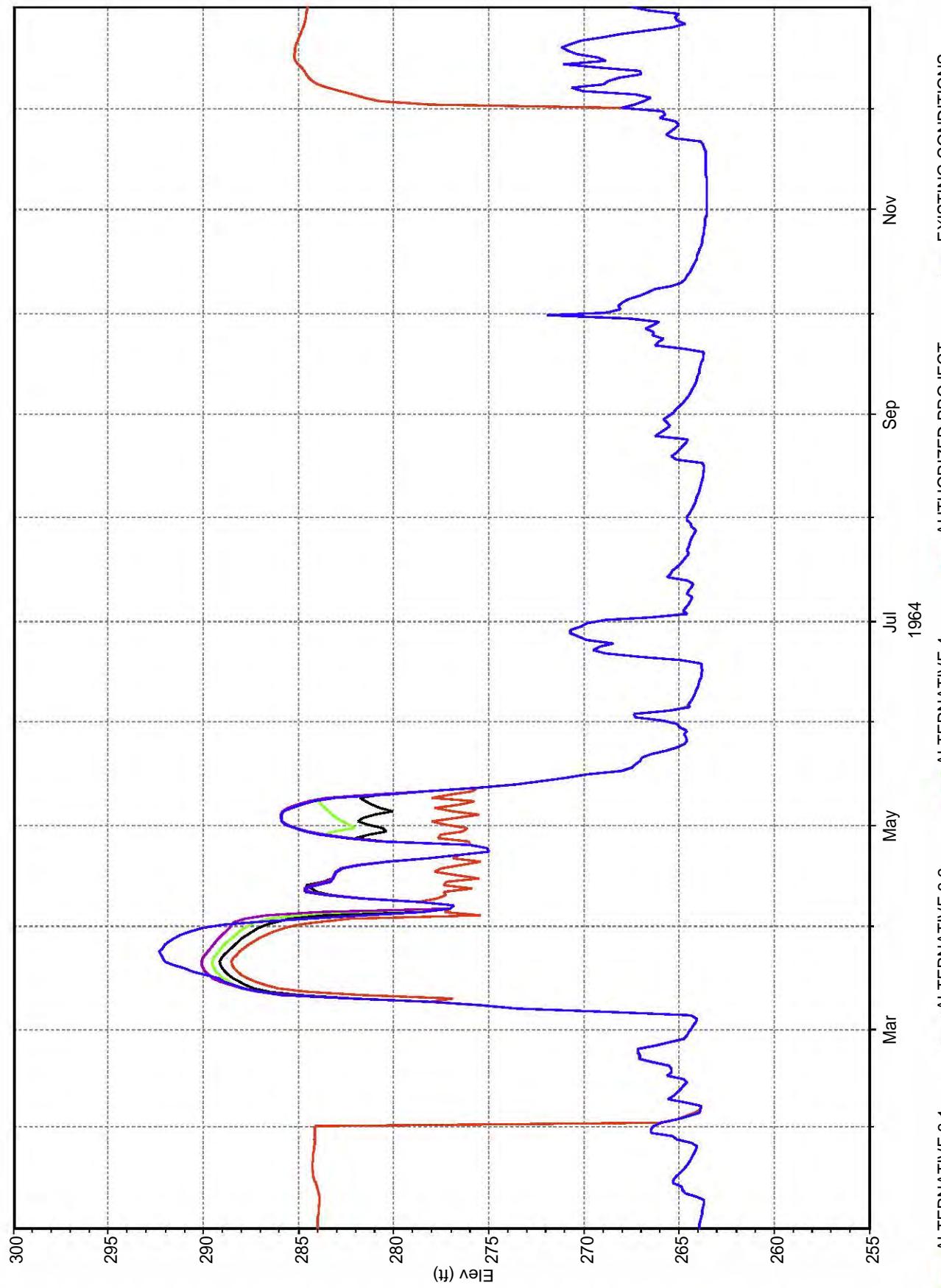


C-112

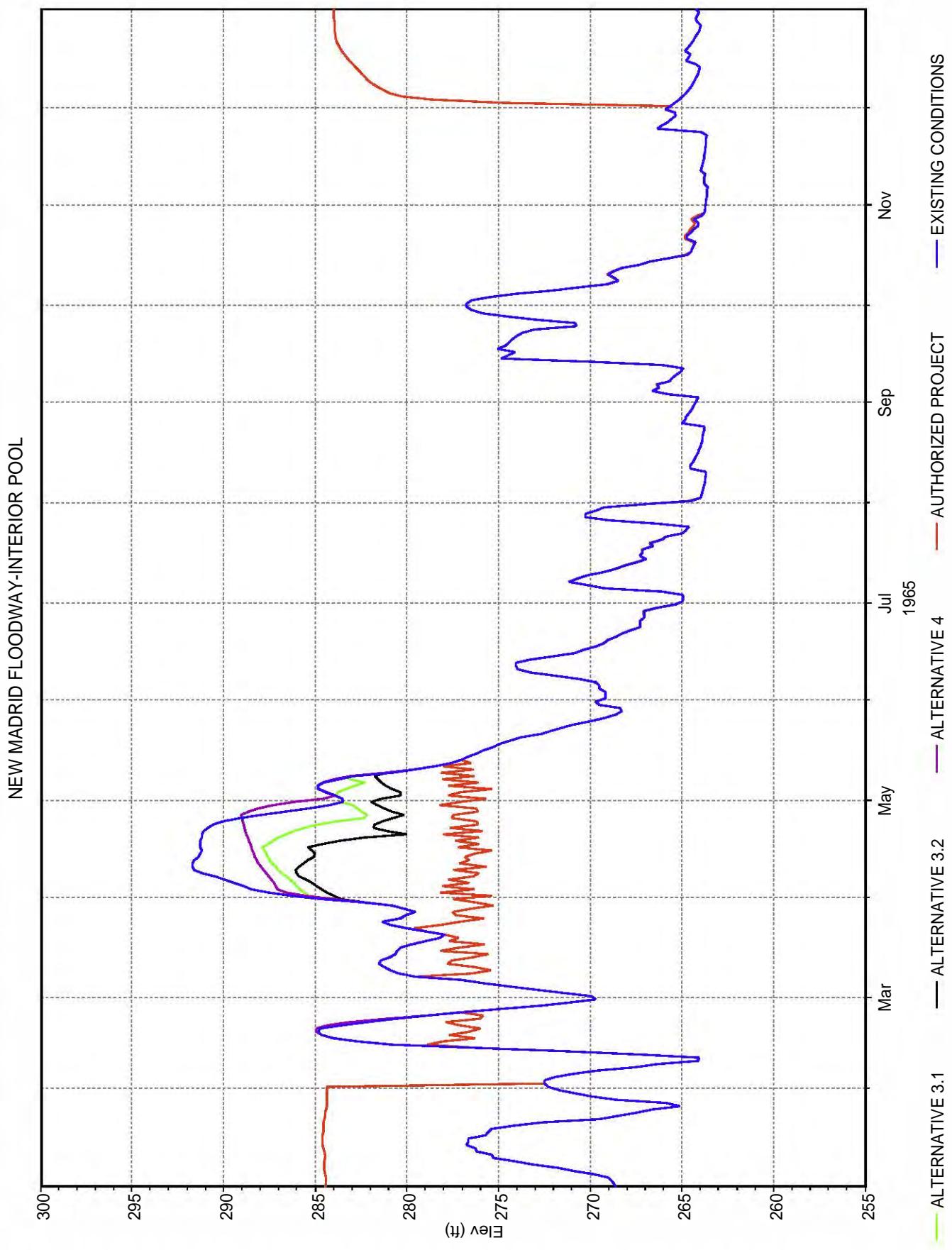


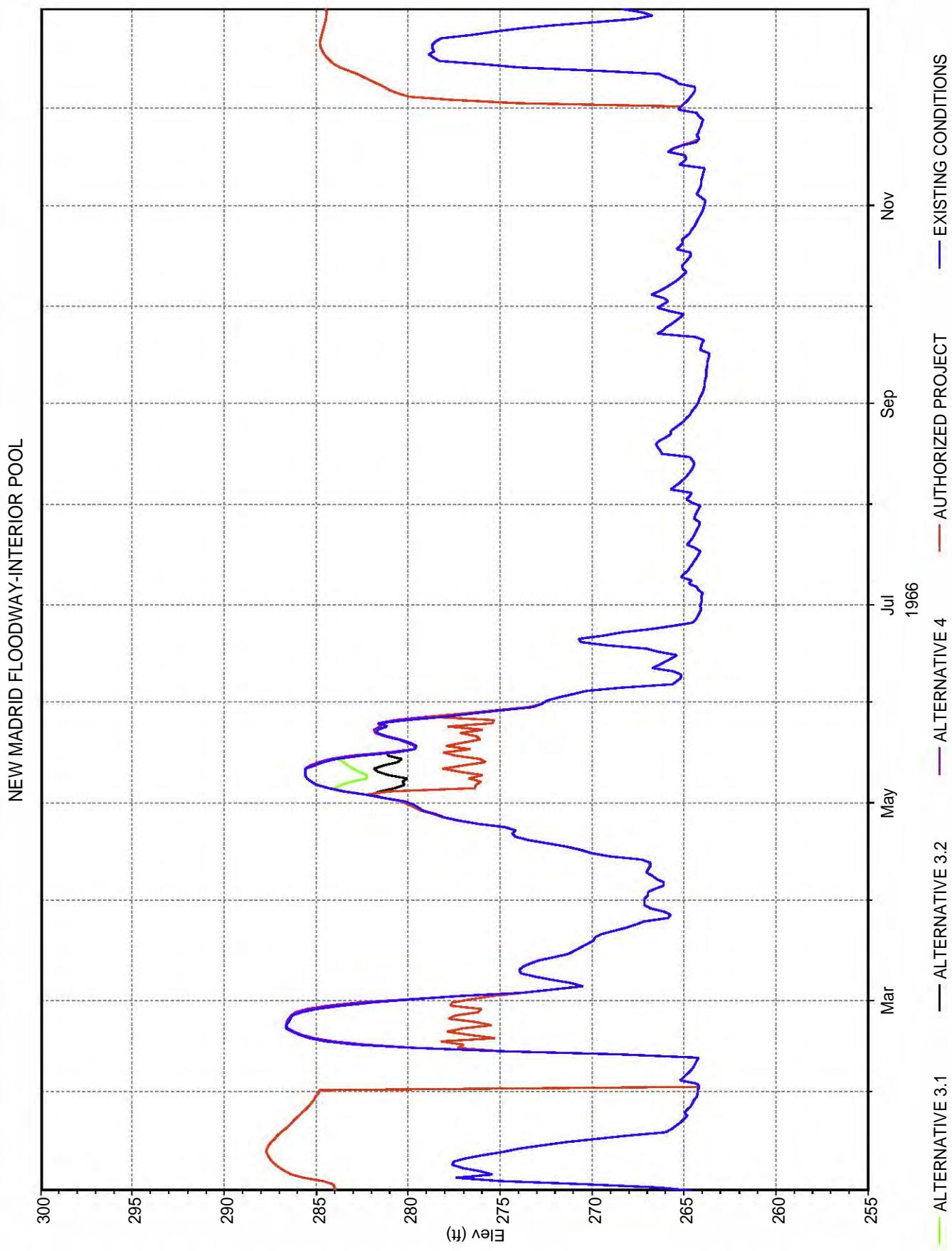


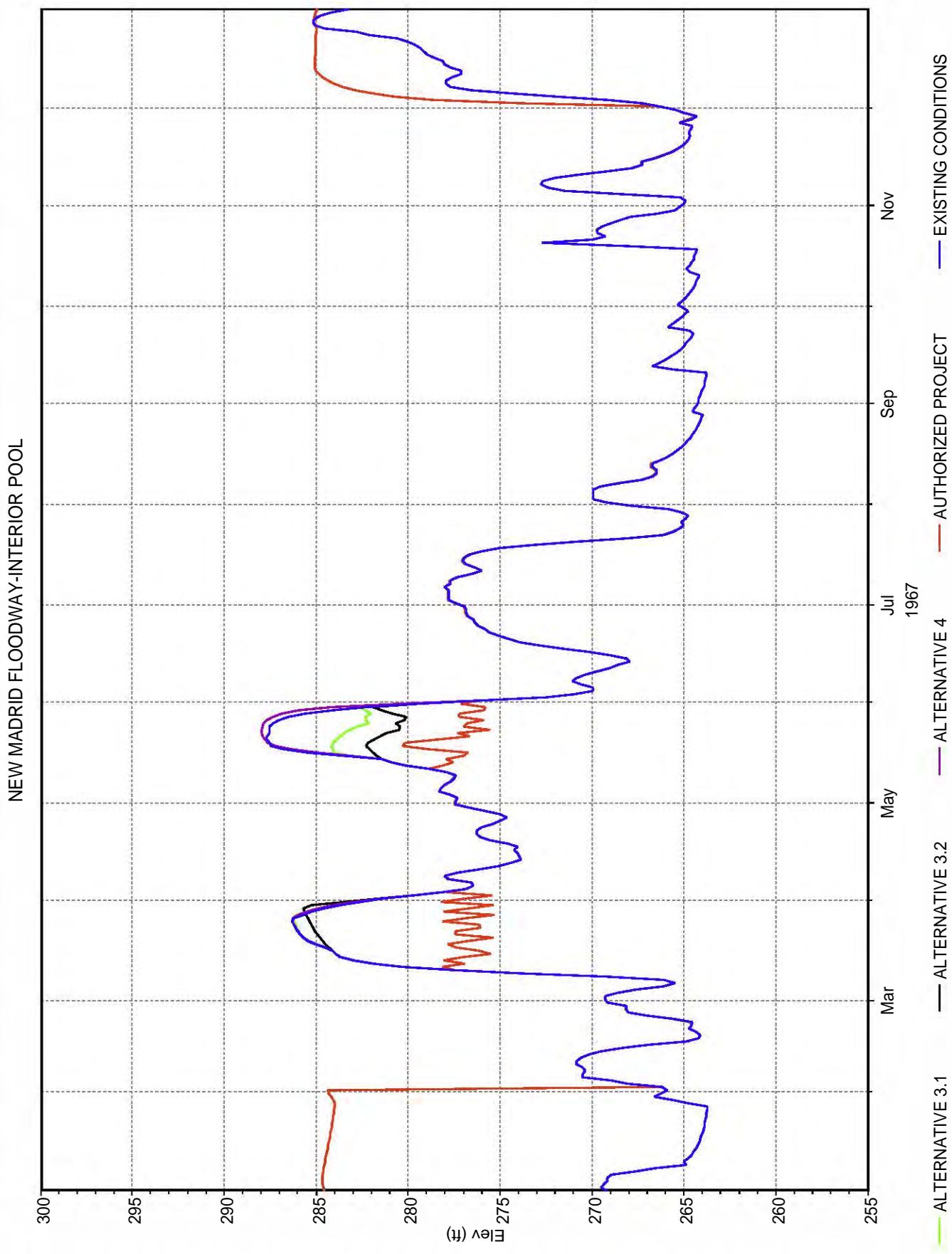
NEW MADRID FLOODWAY-INTERIOR POOL



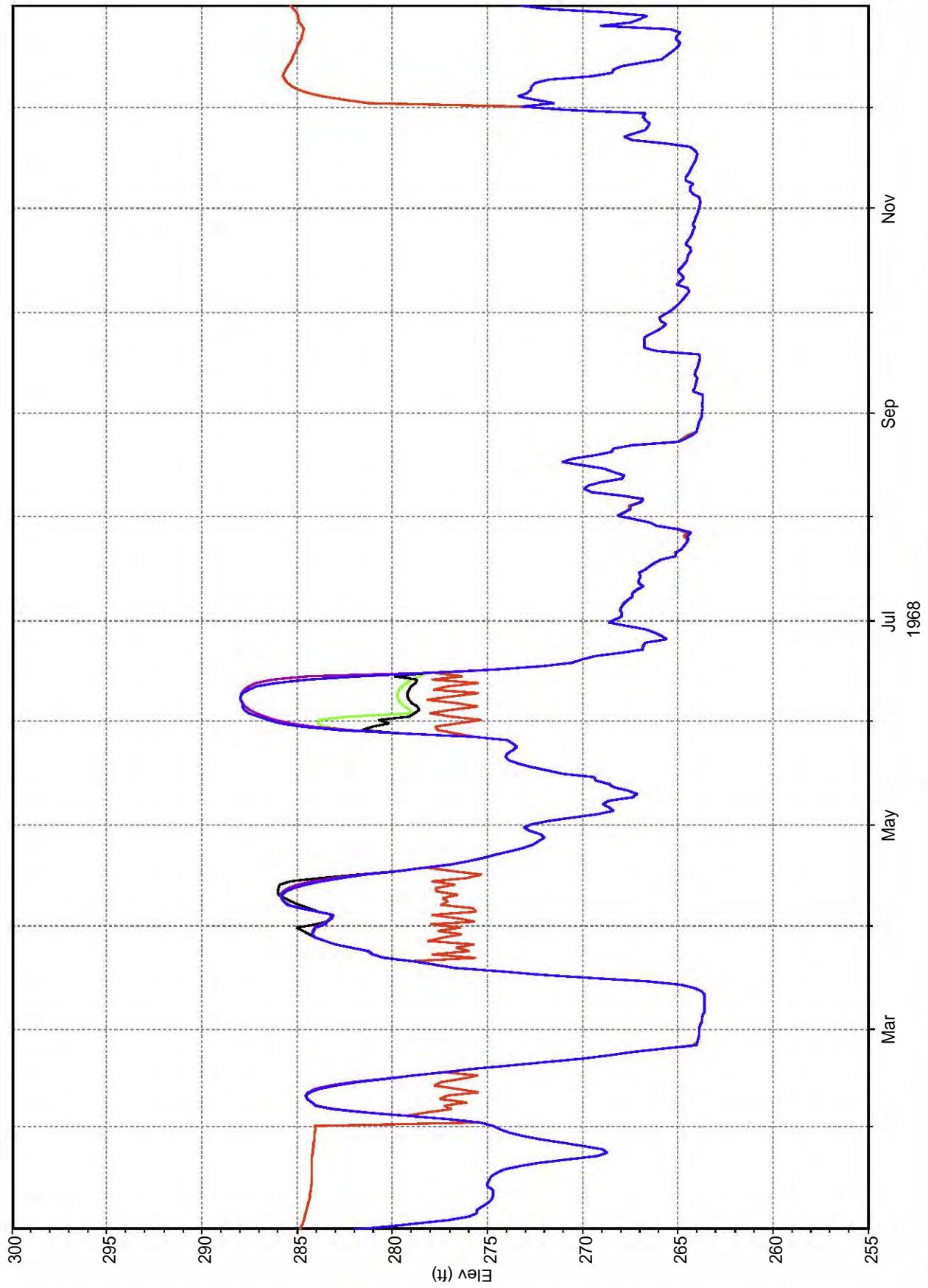
C-115



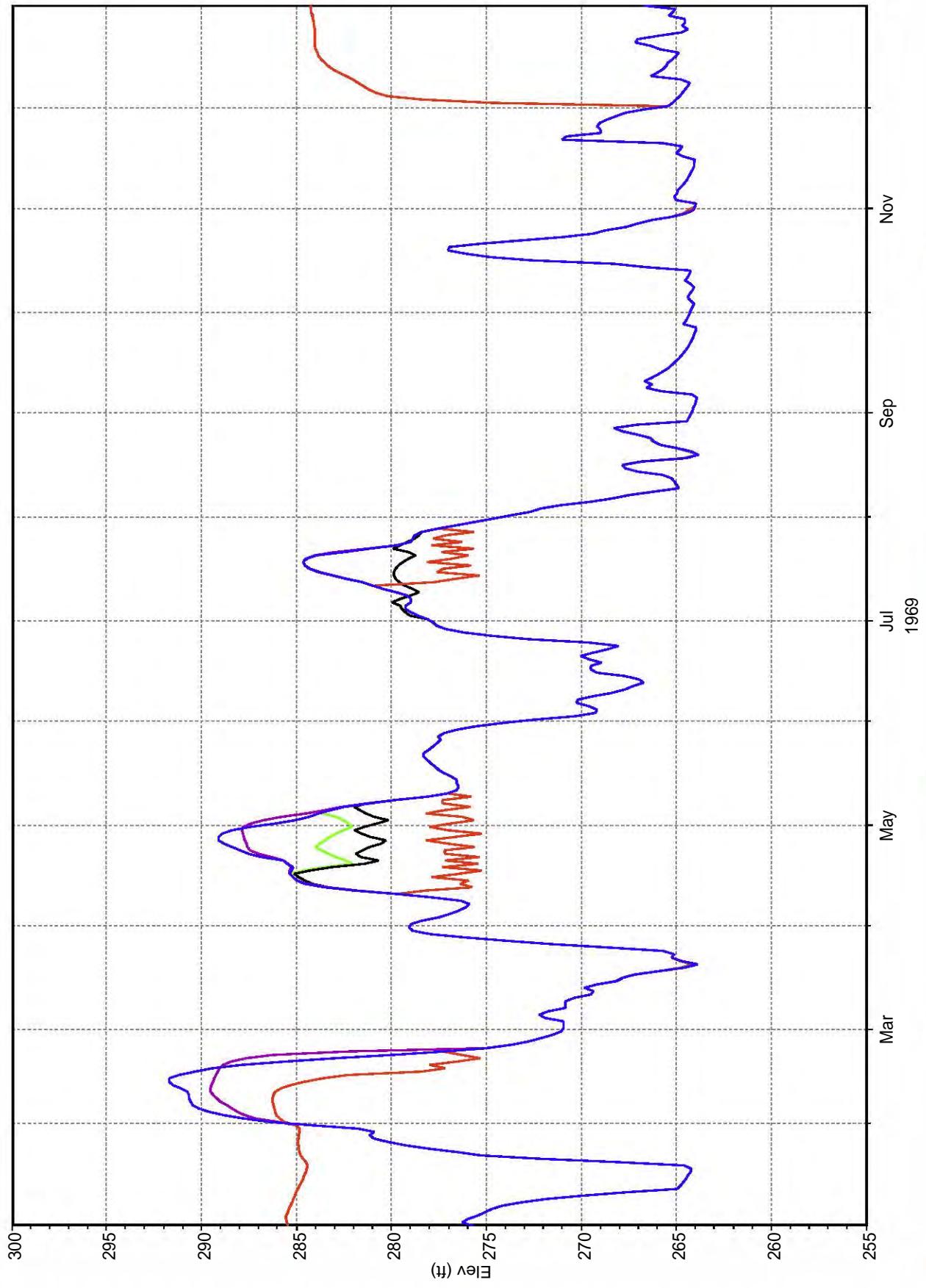




NEW MADRID FLOODWAY-INTERIOR POOL



NEW MADRID FLOODWAY-INTERIOR POOL

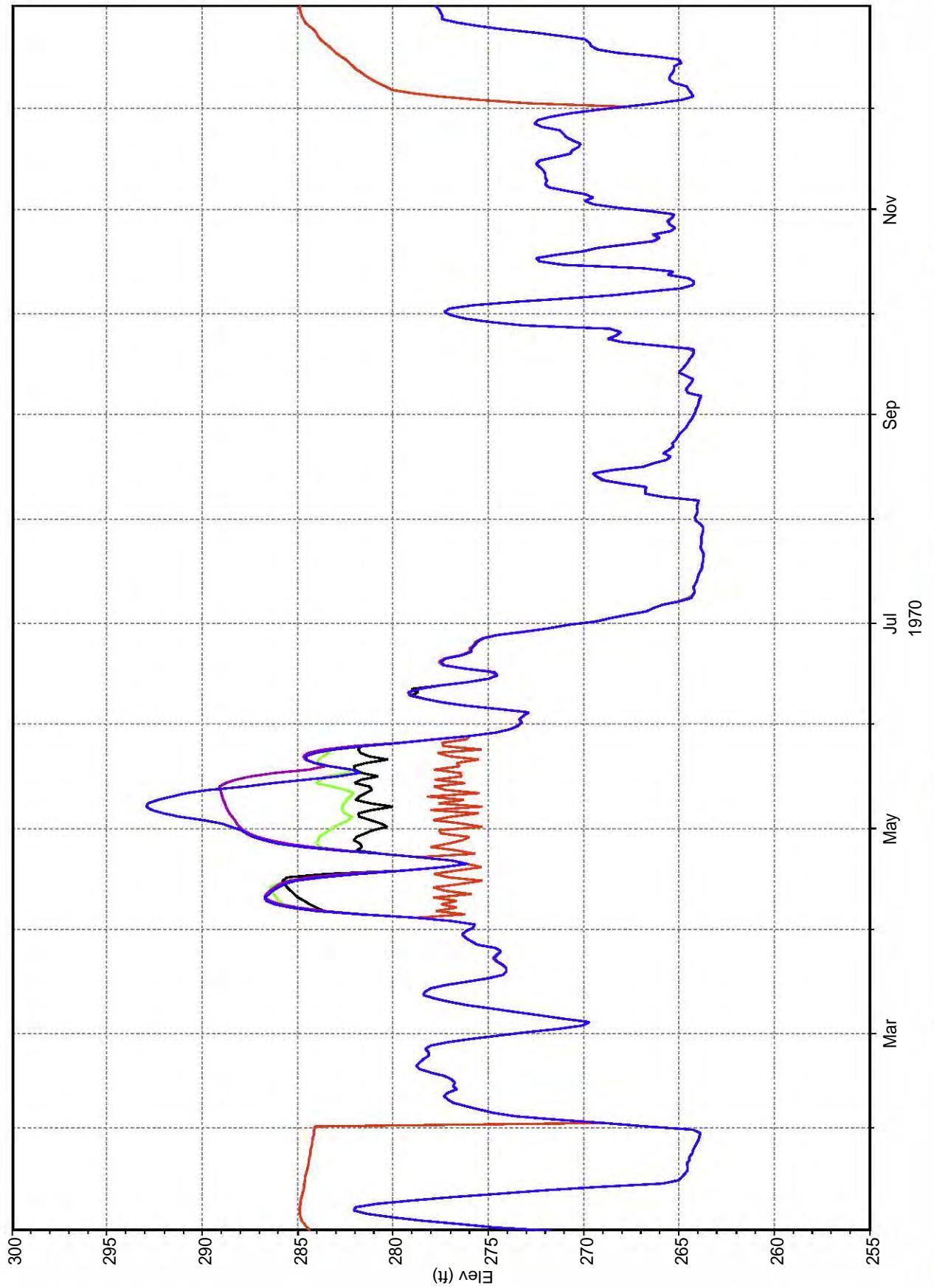


C-120

— ALTERNATIVE 3.1 — ALTERNATIVE 3.2 — ALTERNATIVE 4 — AUTHORIZED PROJECT — EXISTING CONDITIONS

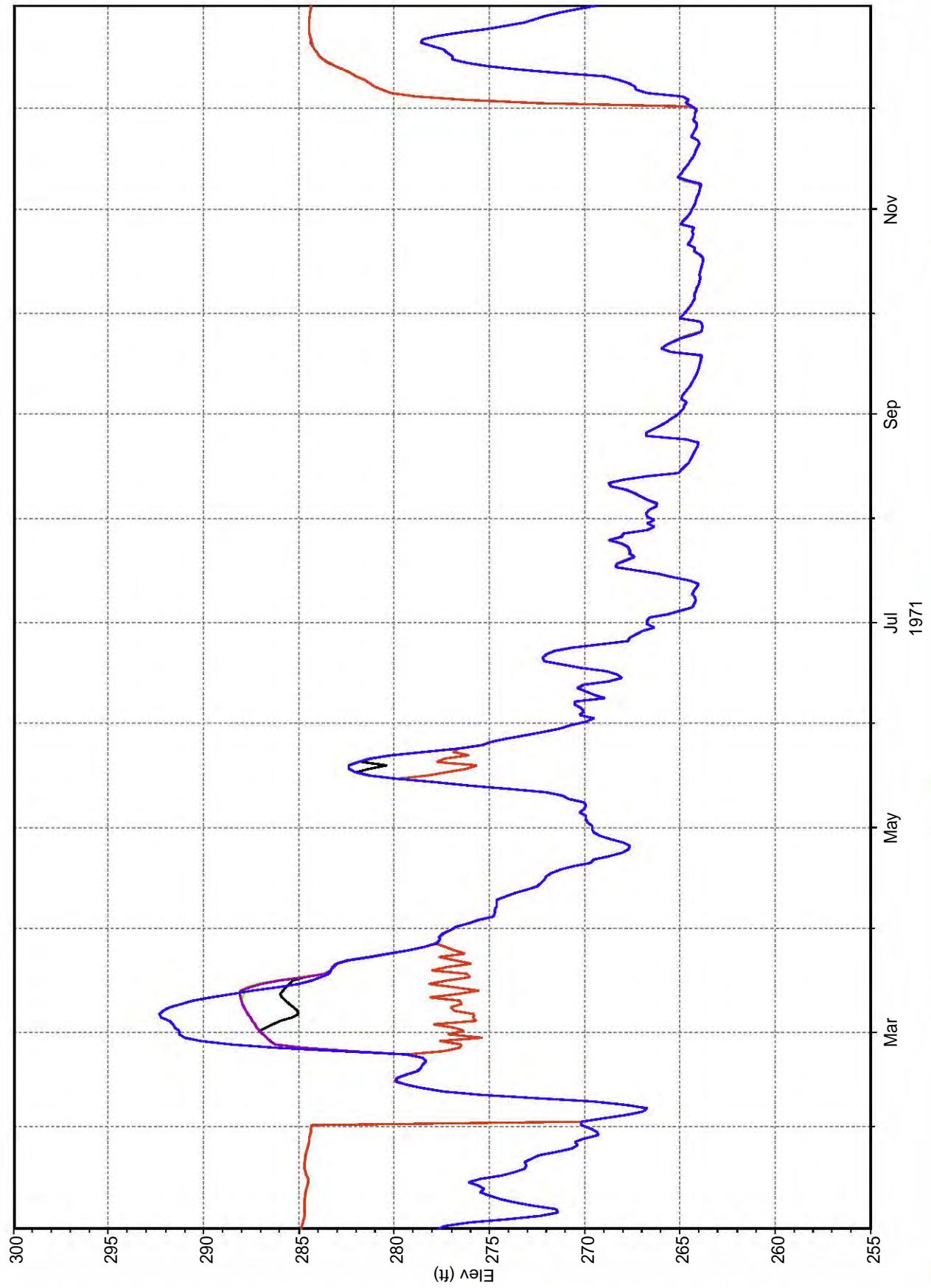
PLATE 100

NEW MADRID FLOODWAY-INTERIOR POOL

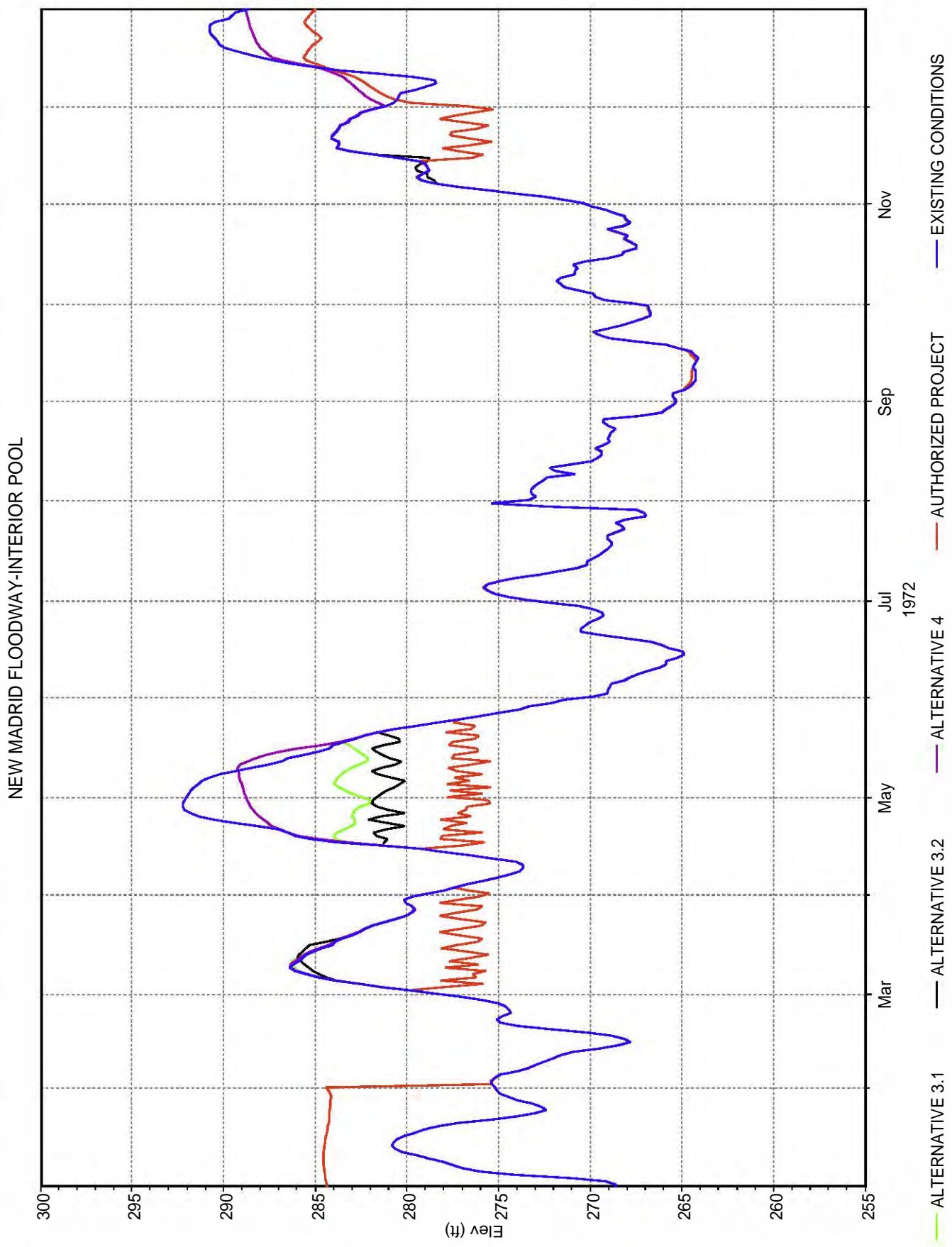


C-121

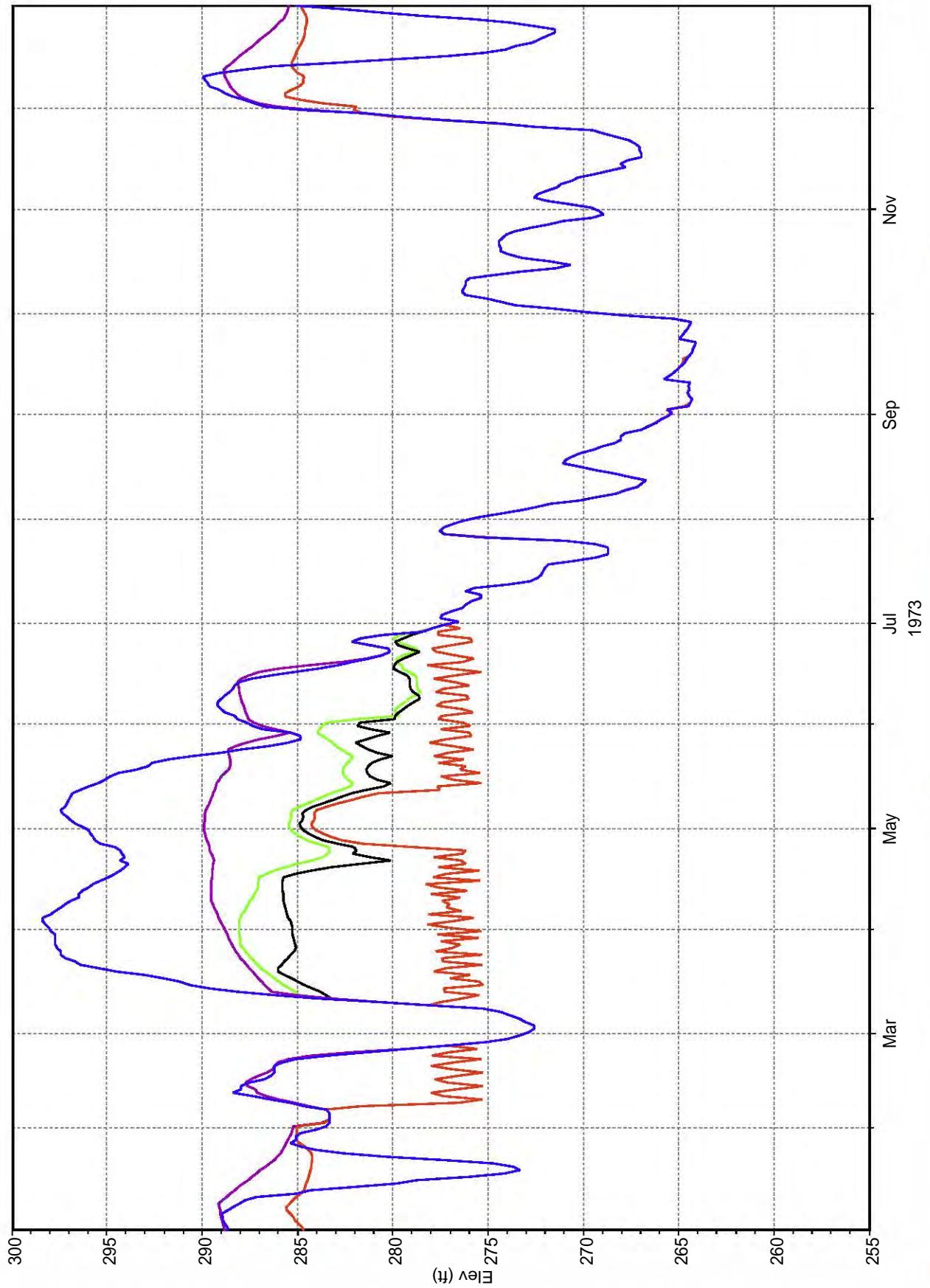
NEW MADRID FLOODWAY-INTERIOR POOL



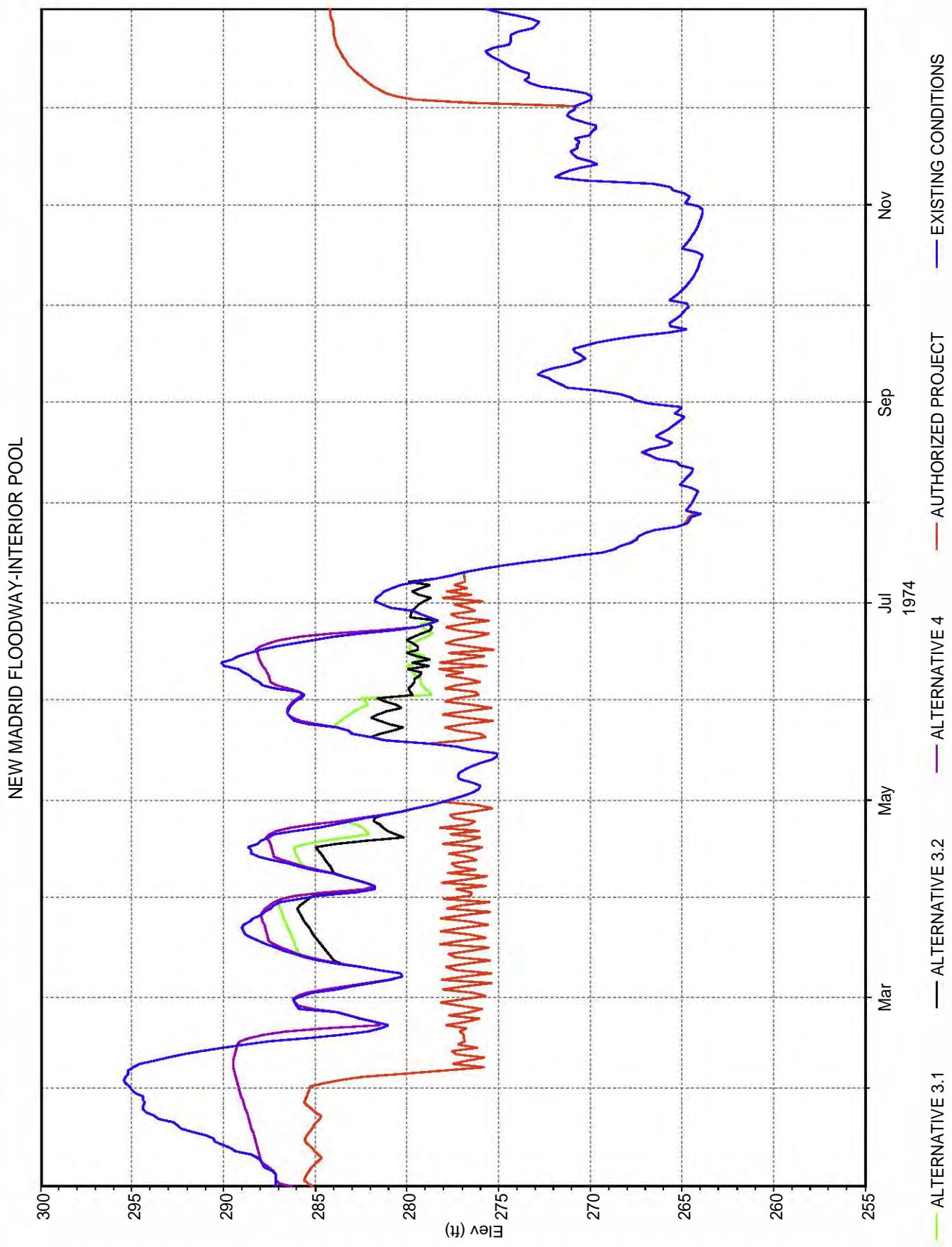
C-122



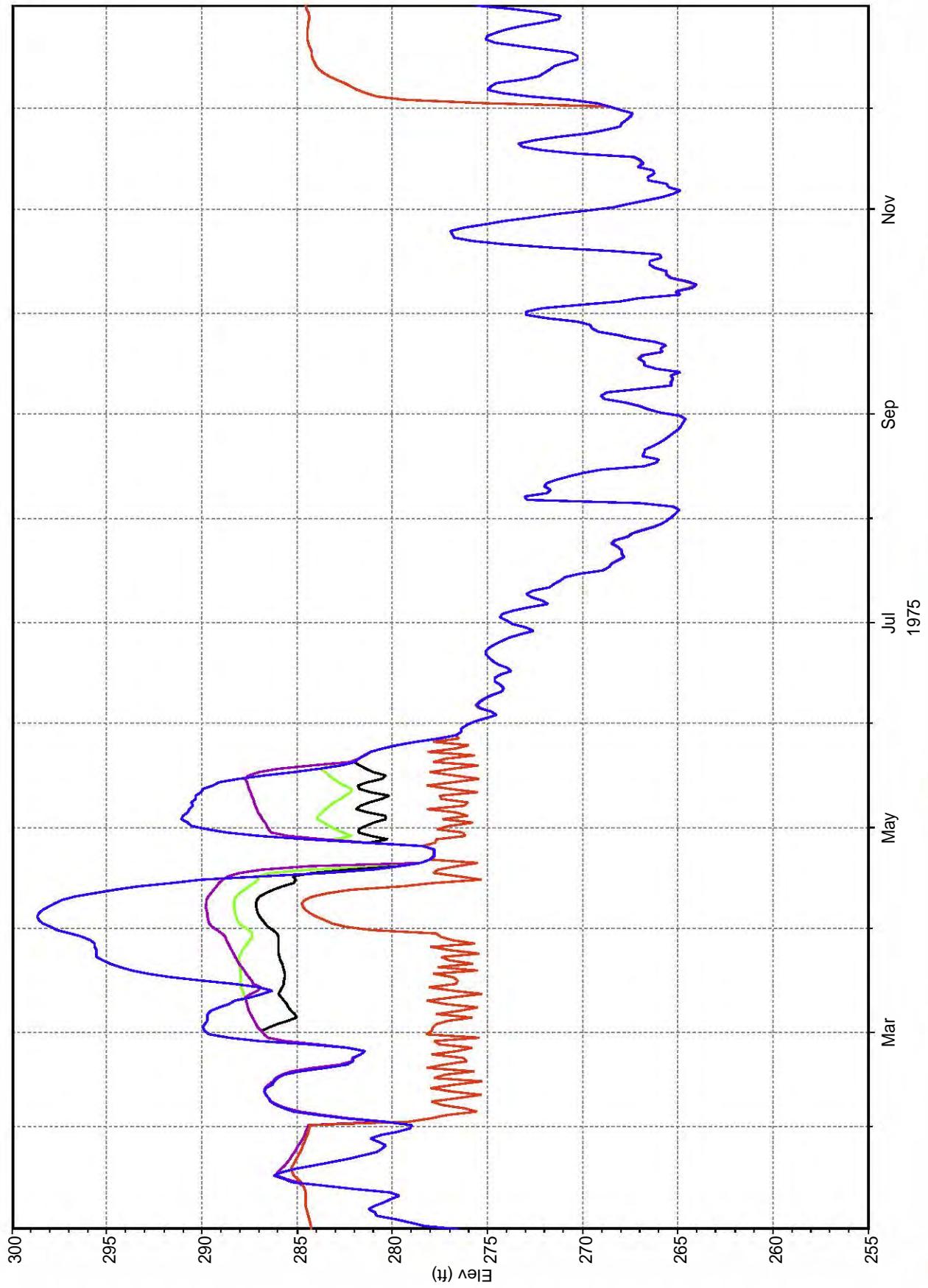
NEW MADRID FLOODWAY-INTERIOR POOL



C-124

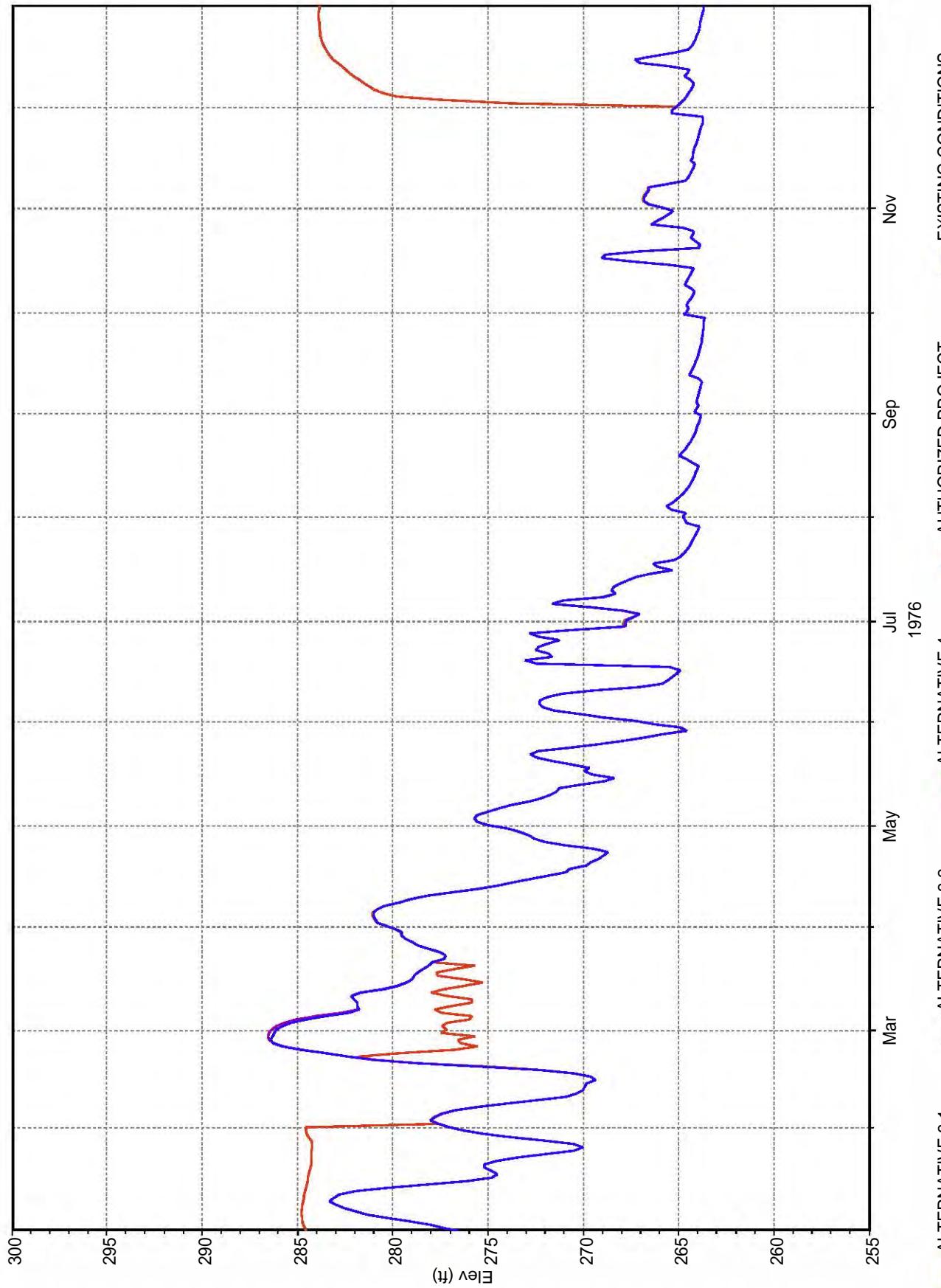


NEW MADRID FLOODWAY-INTERIOR POOL

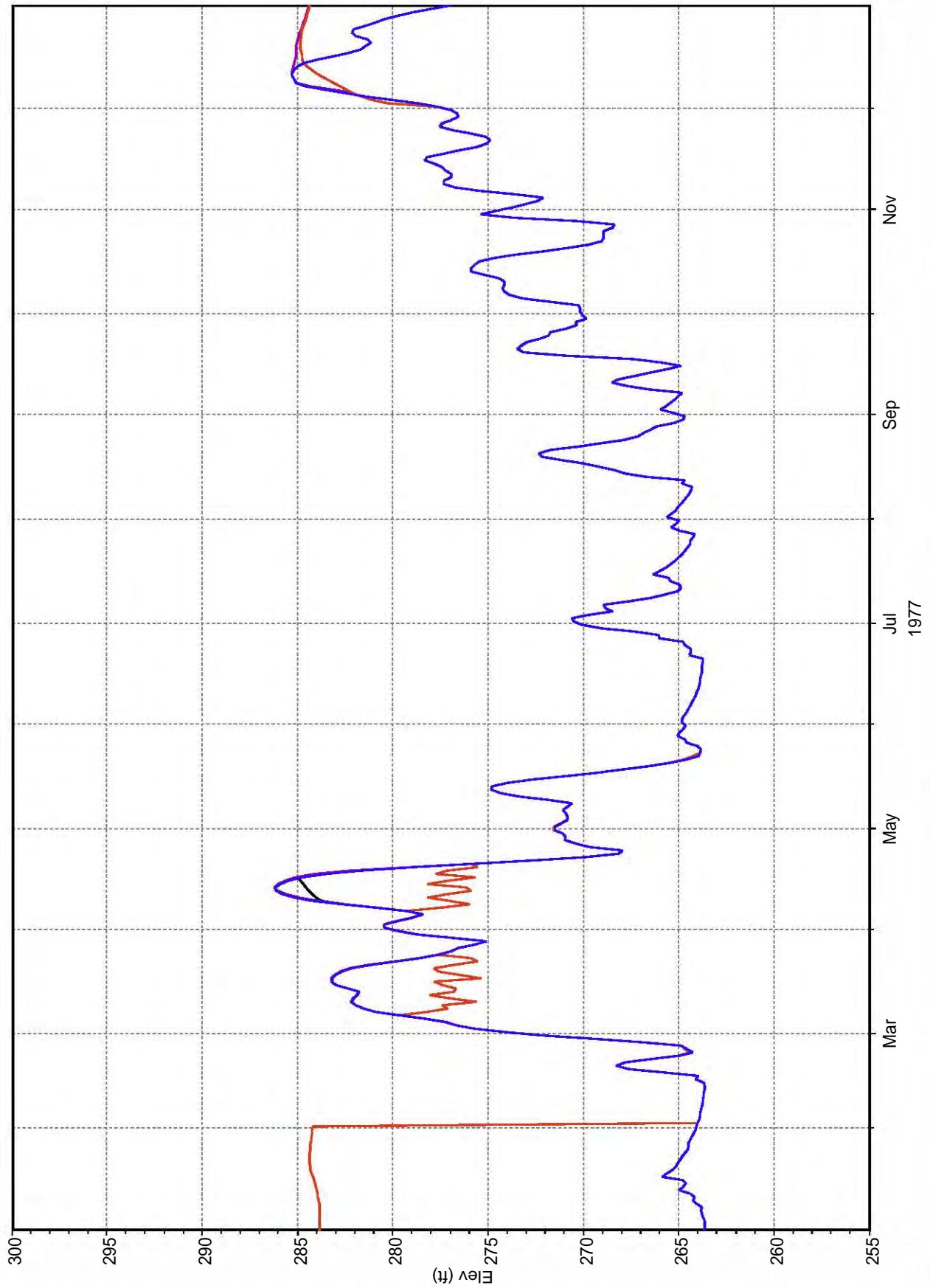


C-126

NEW MADRID FLOODWAY-INTERIOR POOL



NEW MADRID FLOODWAY-INTERIOR POOL

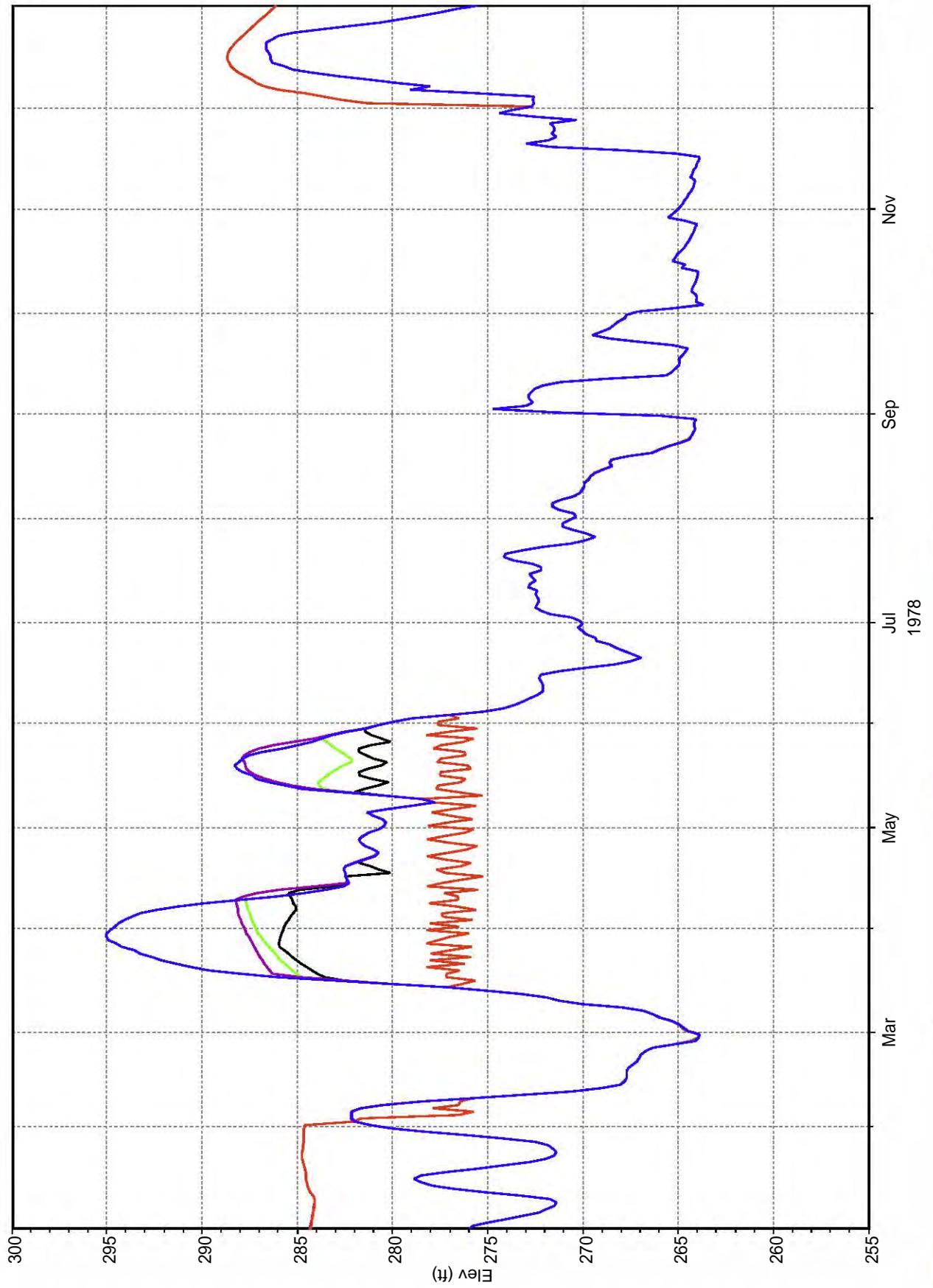


C-128

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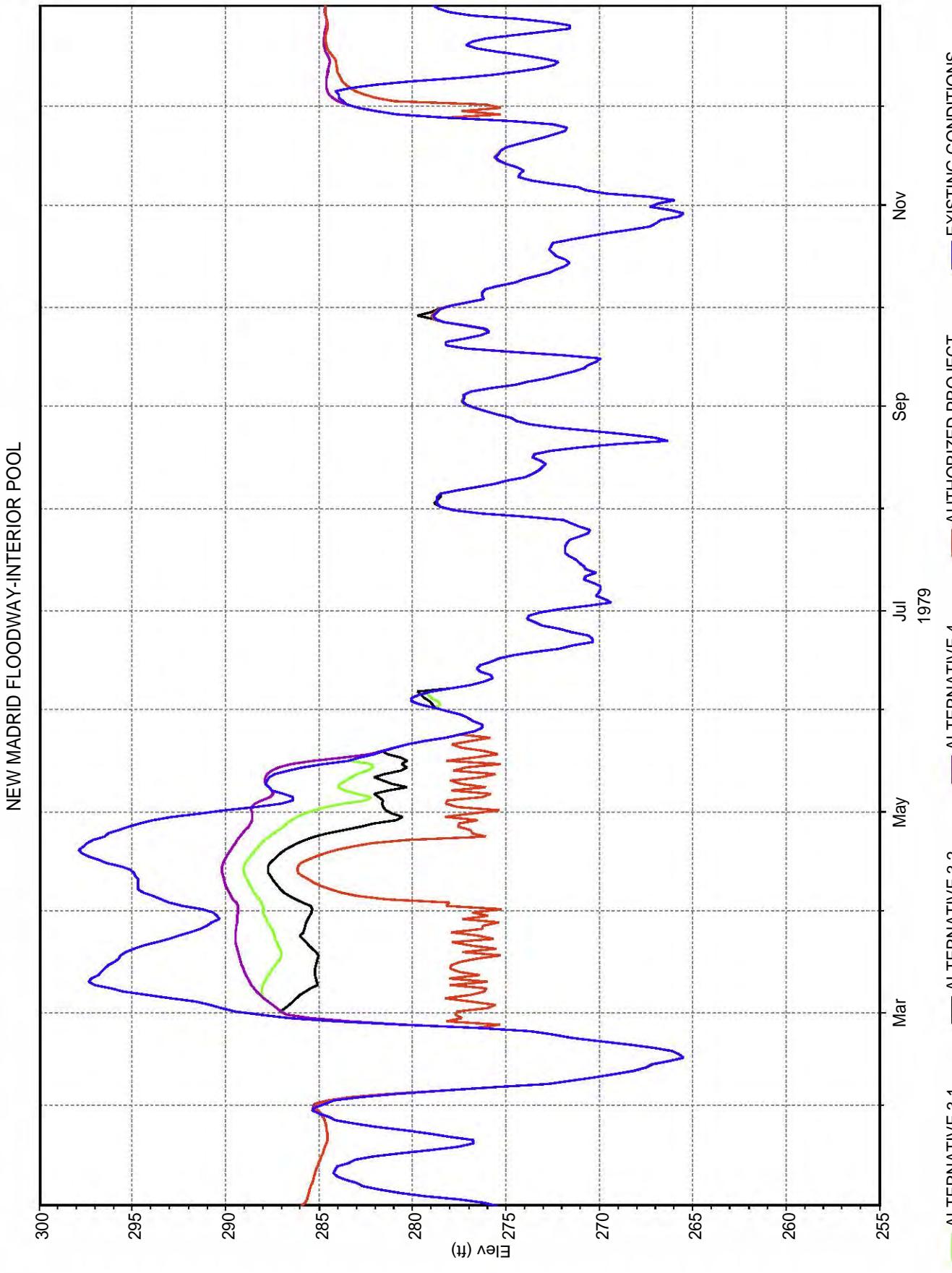
PLATE 108

NEW MADRID FLOODWAY-INTERIOR POOL



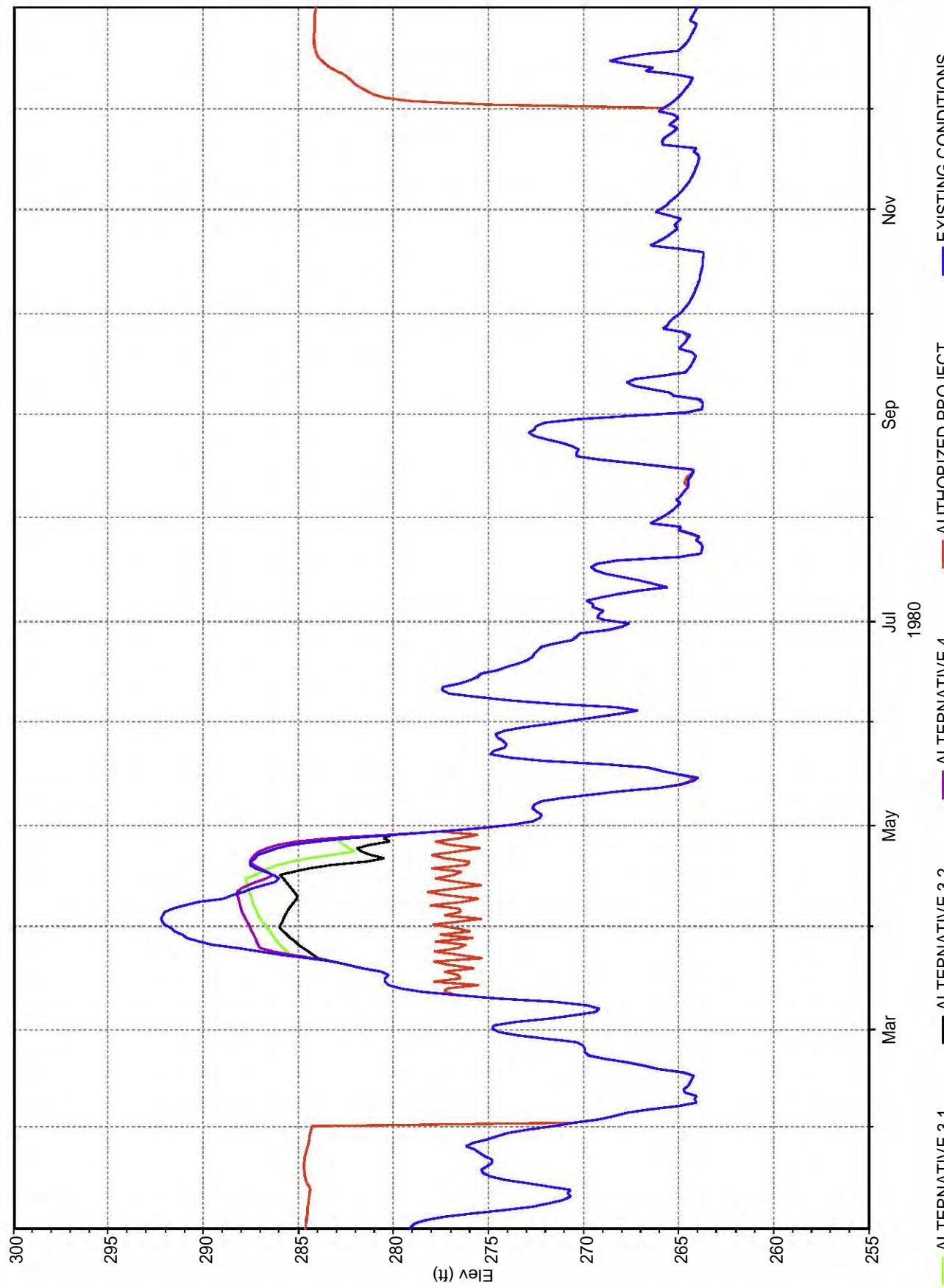
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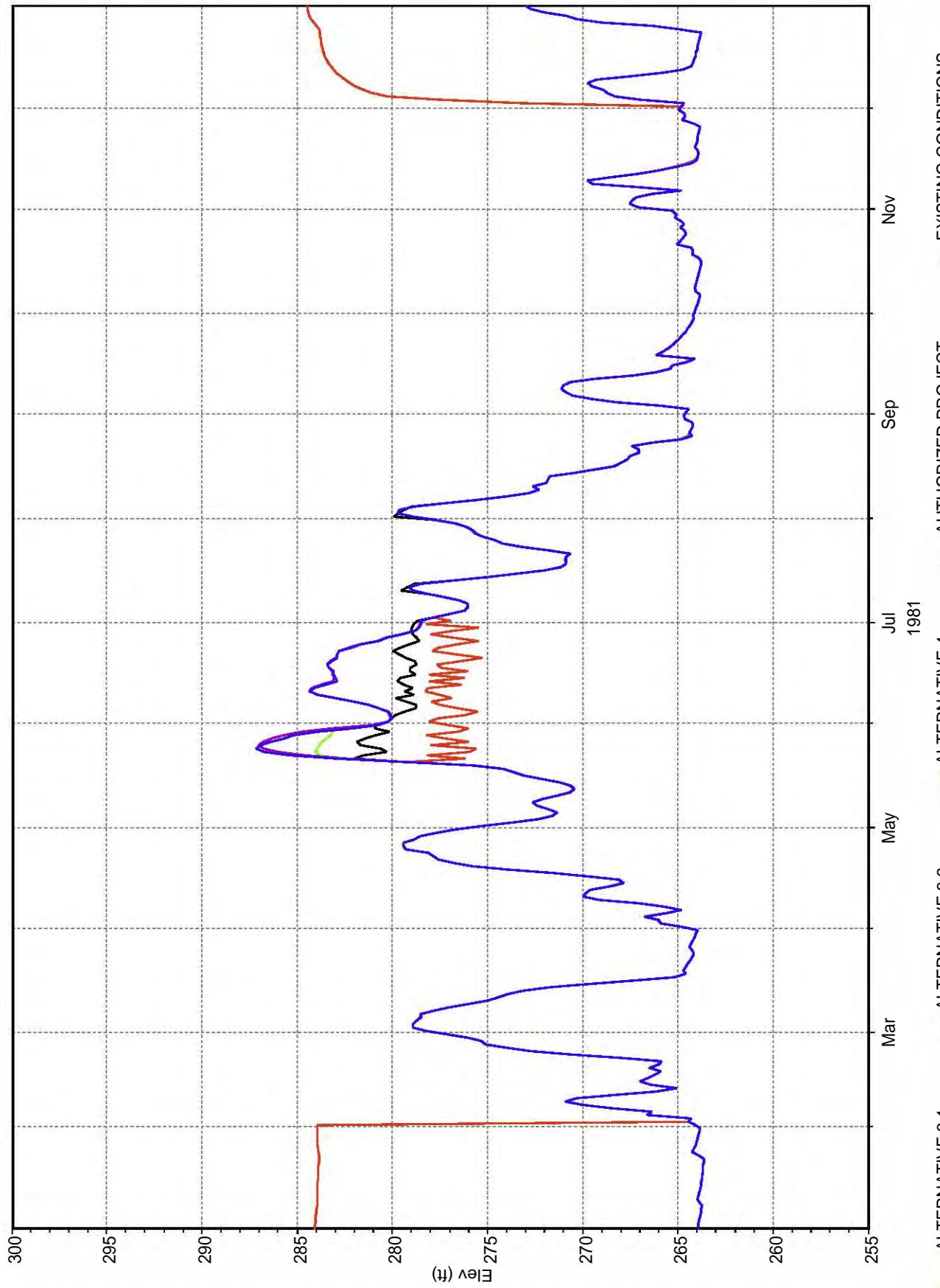


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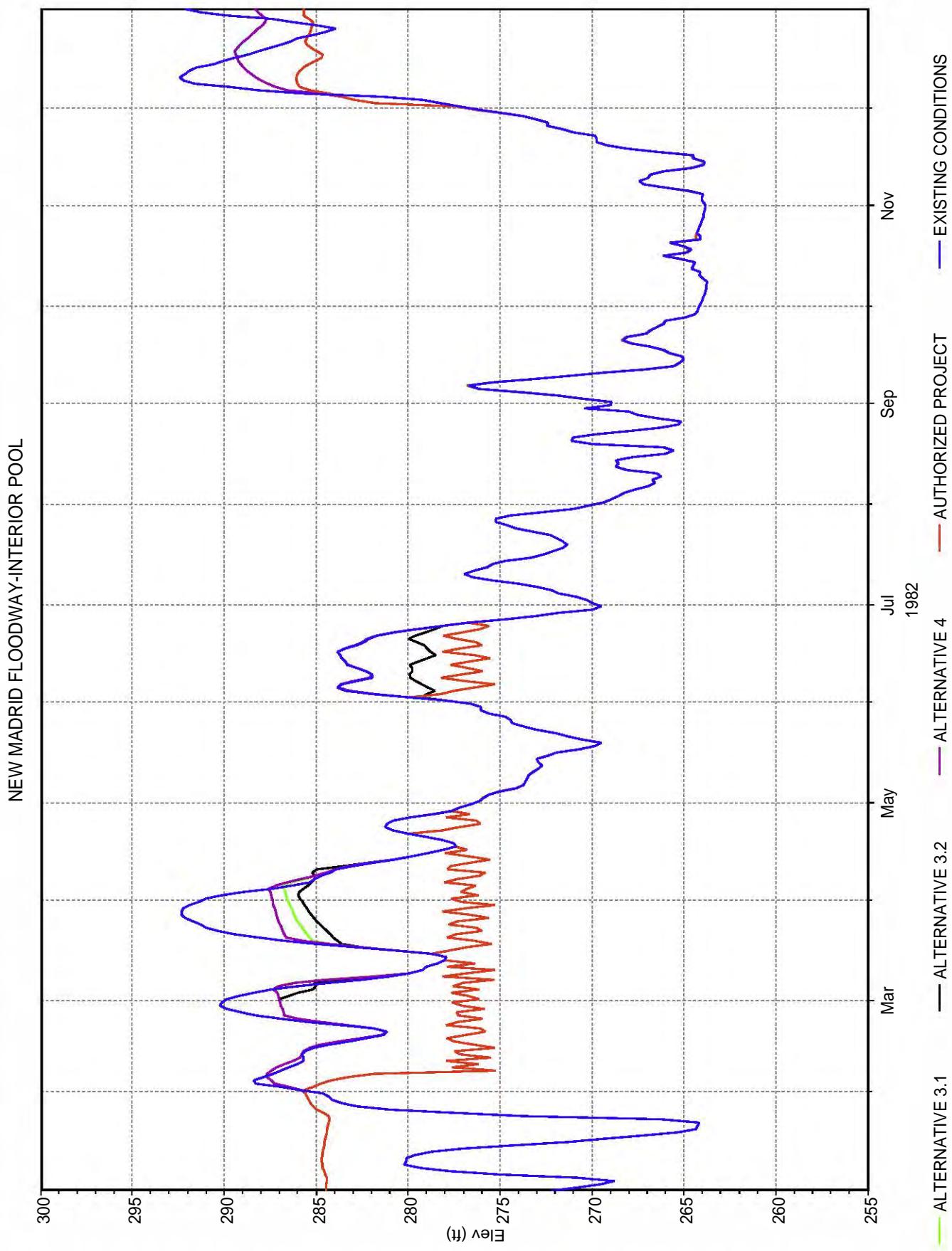


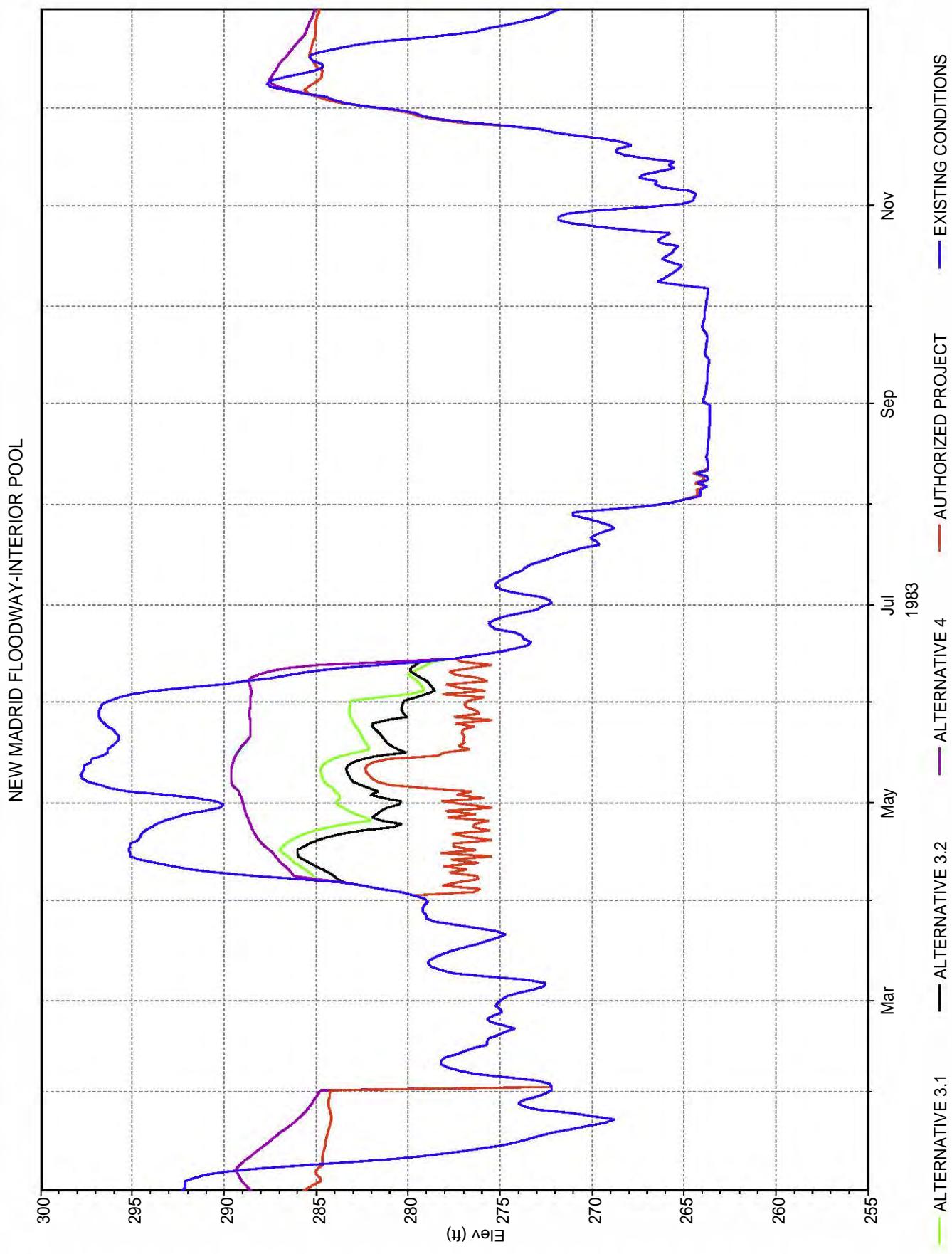
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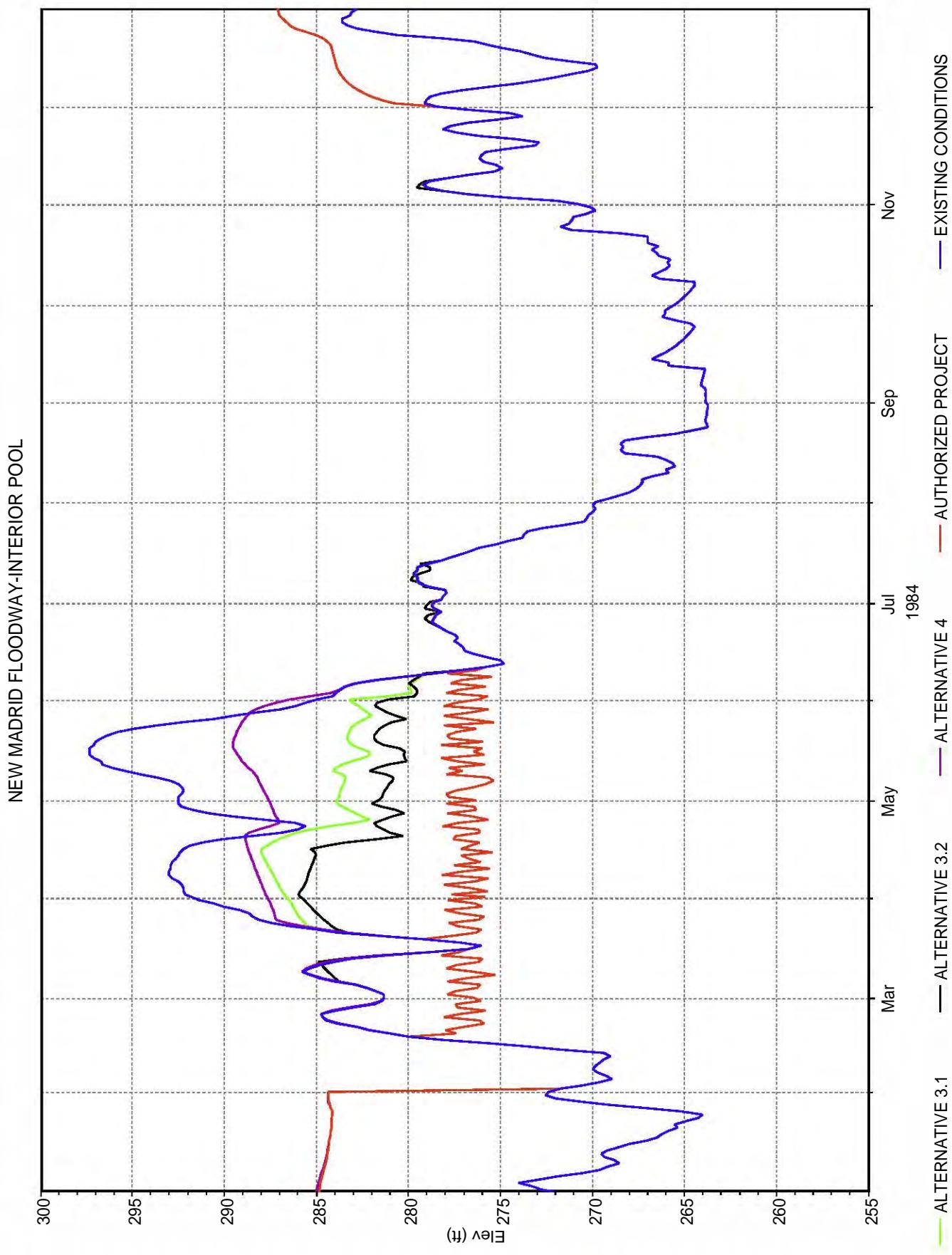


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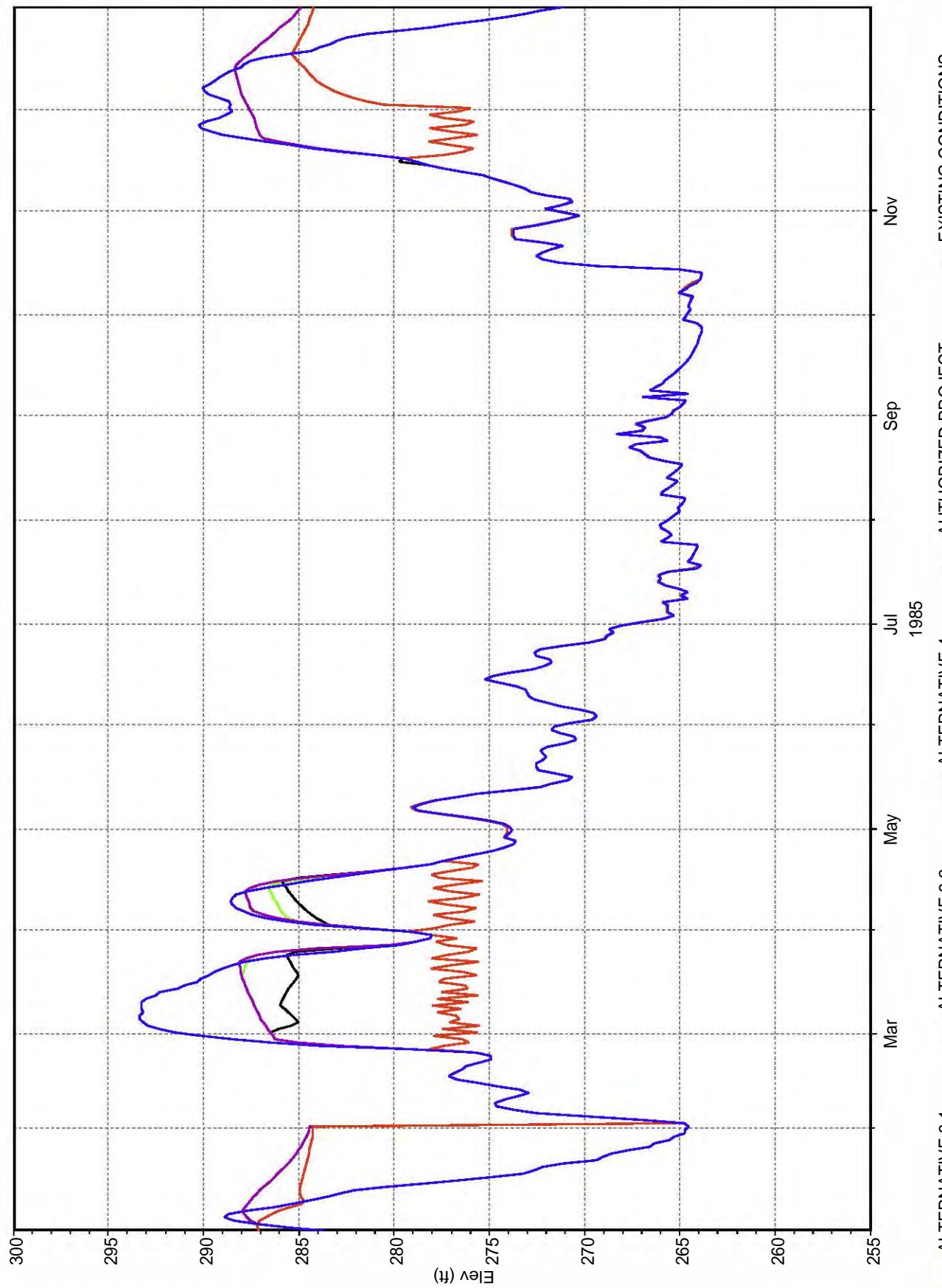
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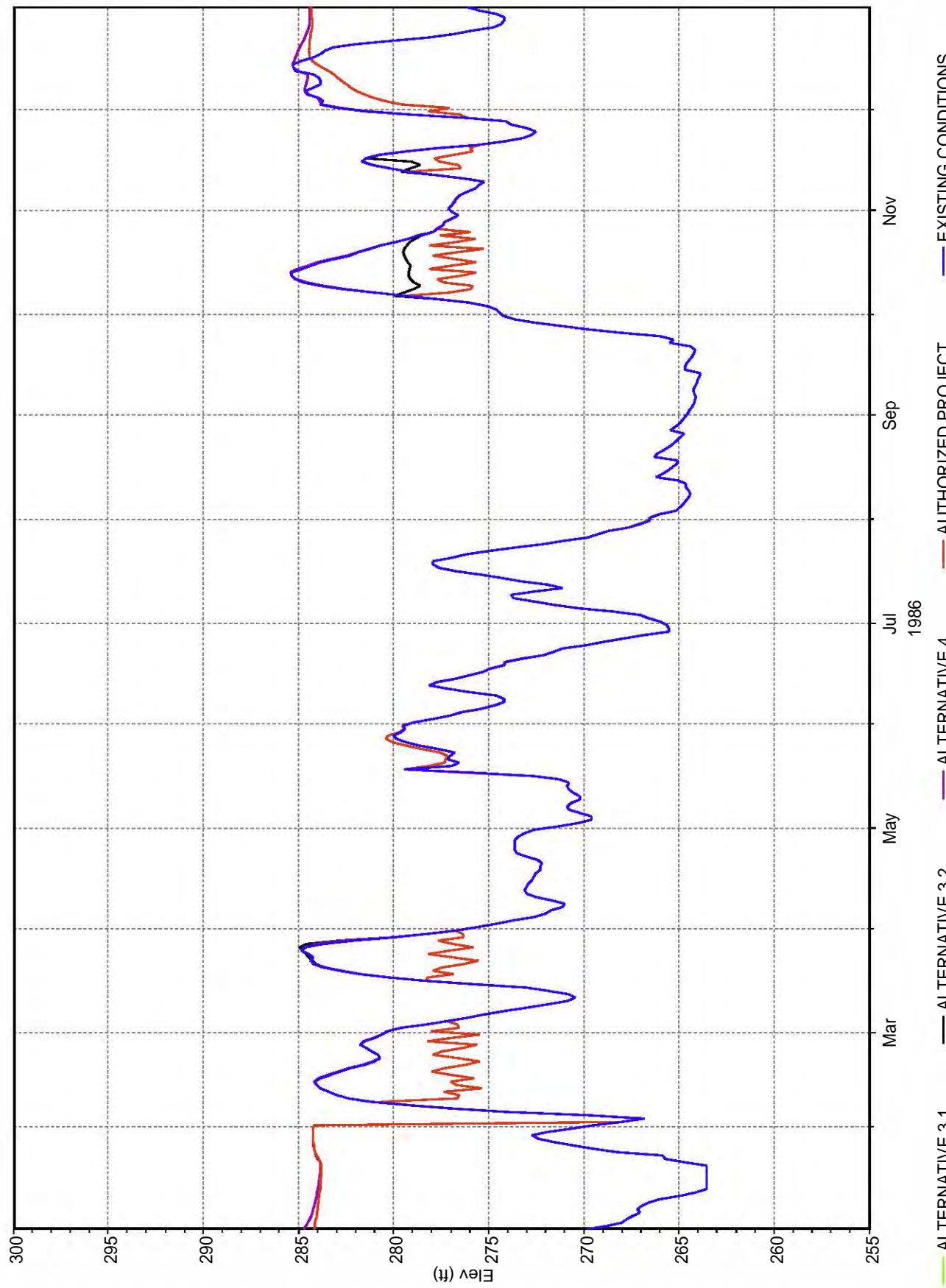


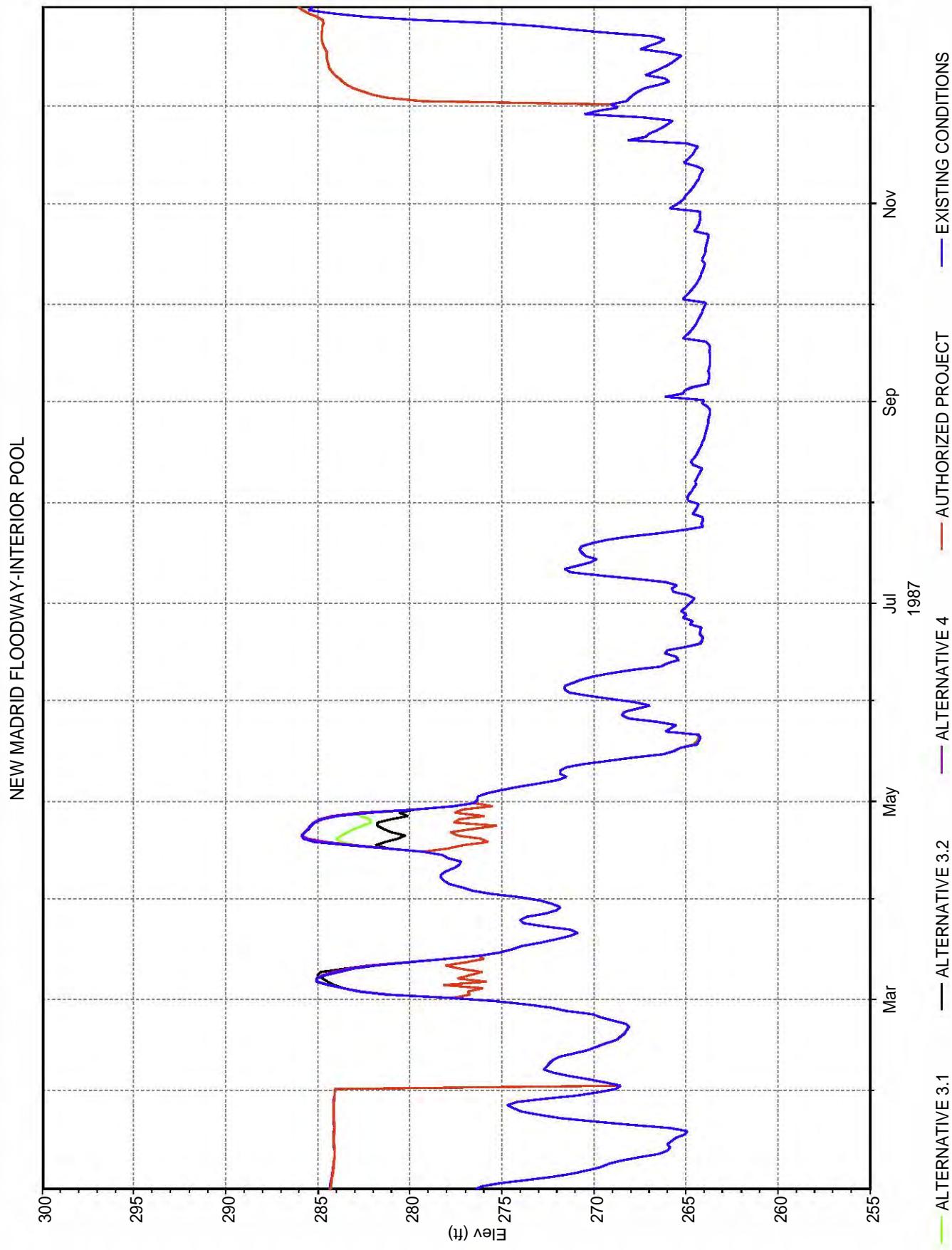
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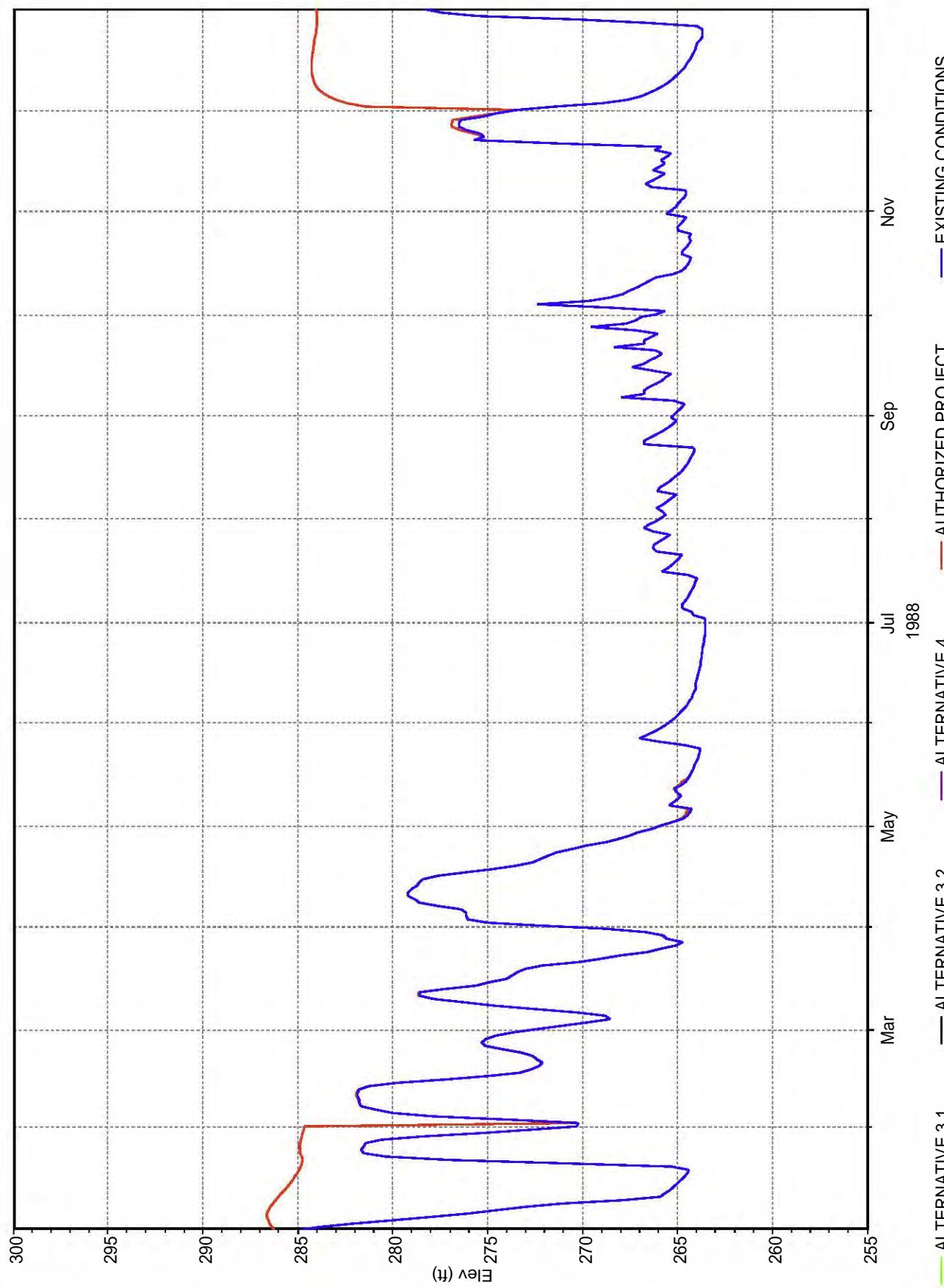
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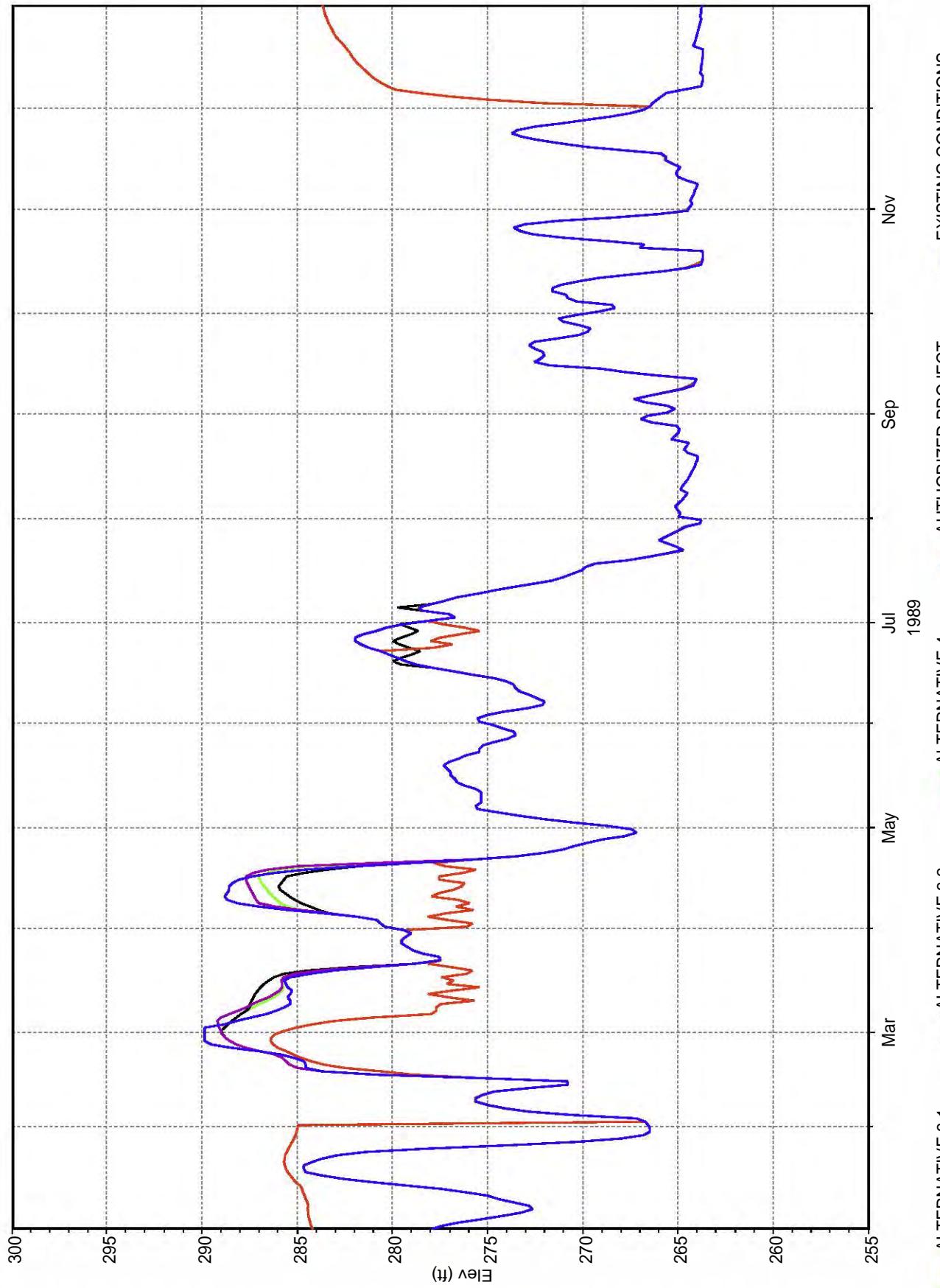


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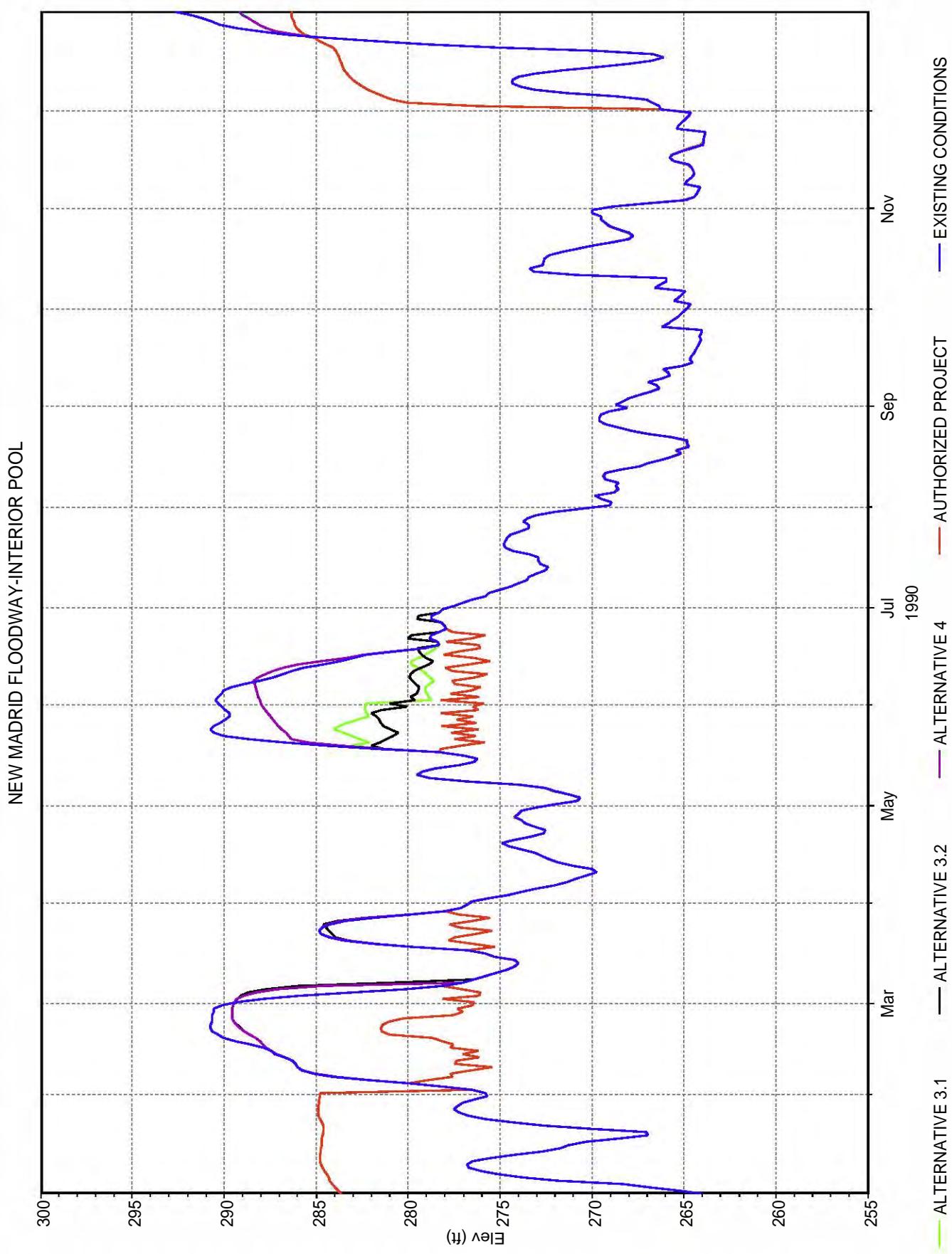
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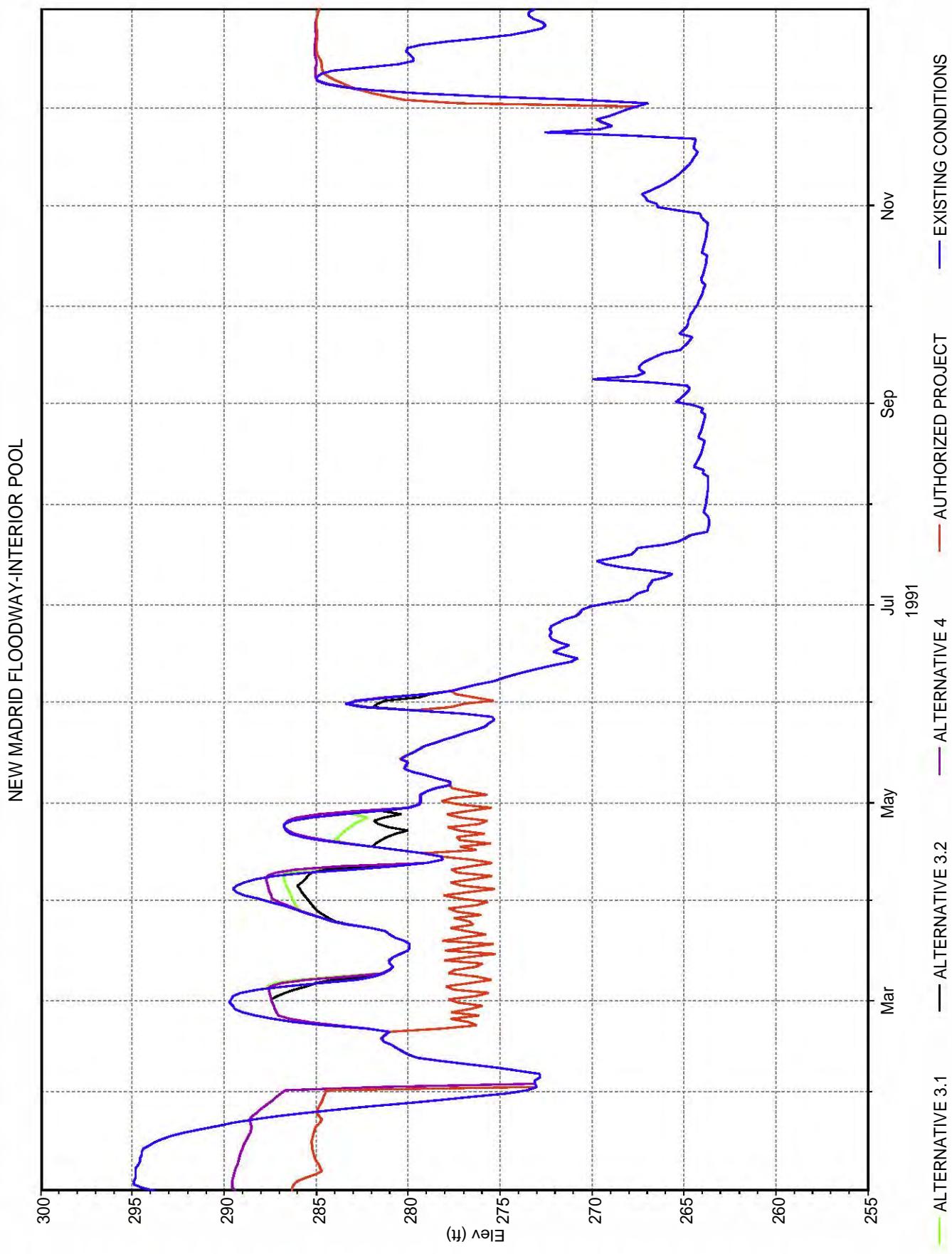
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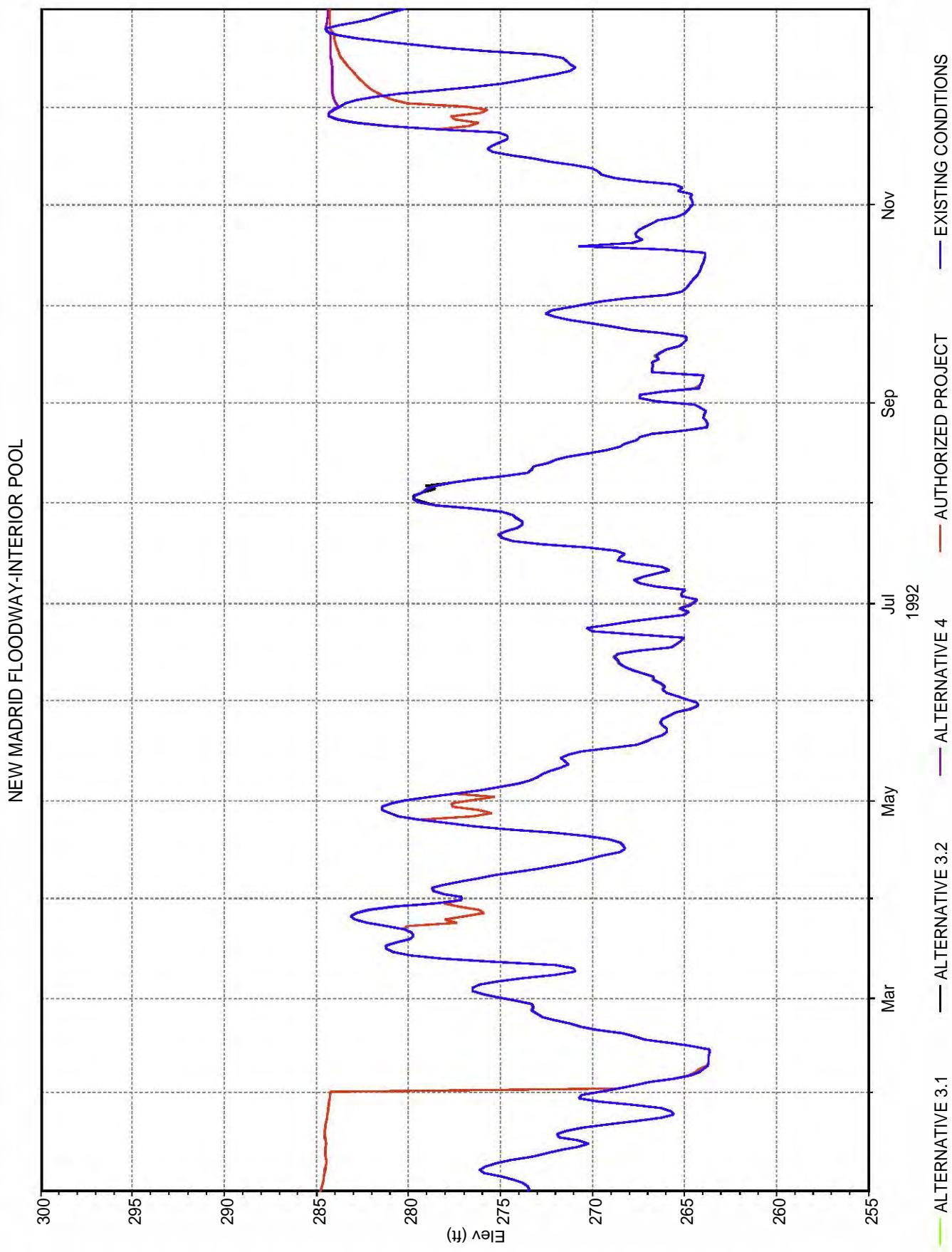


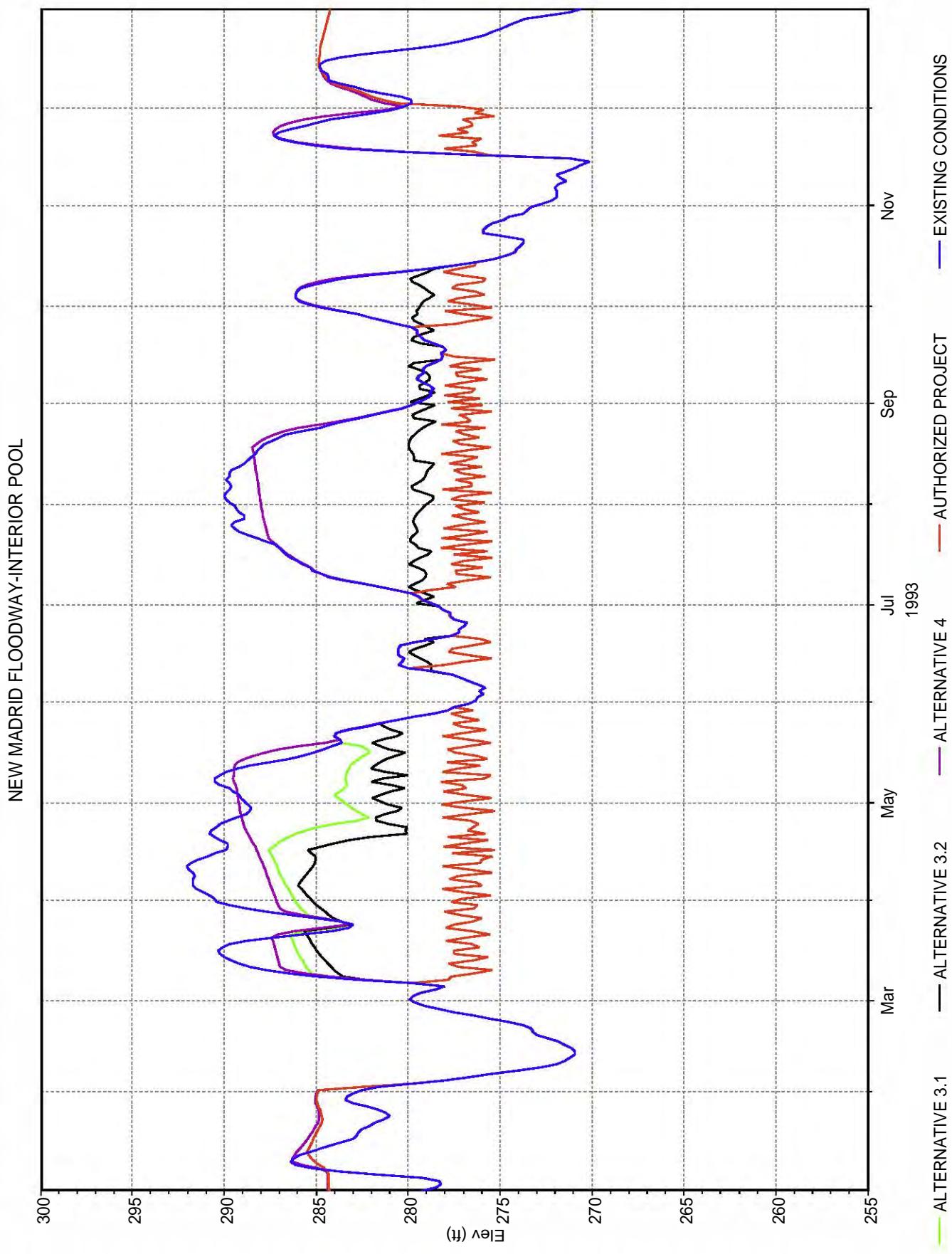
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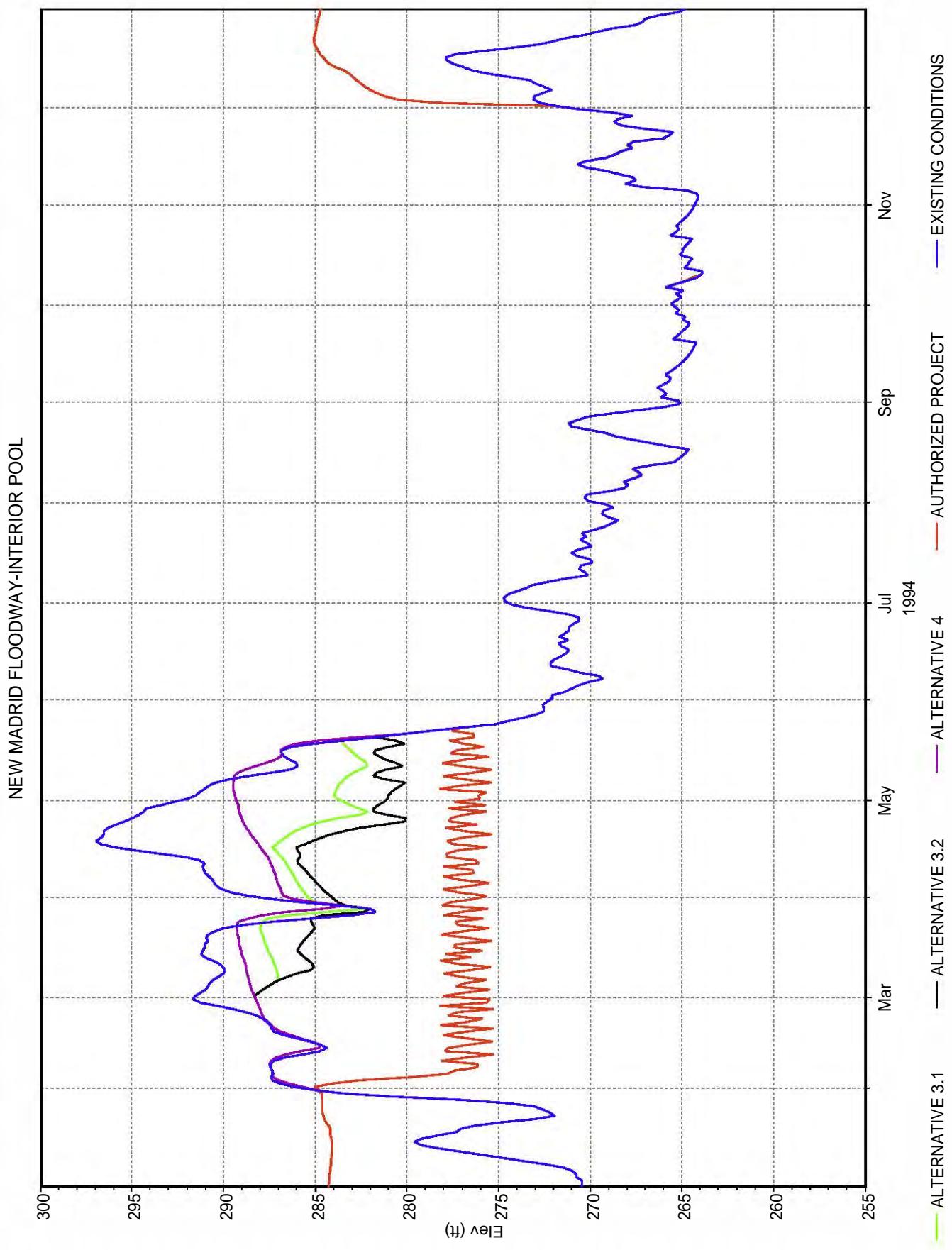
PLATE 120



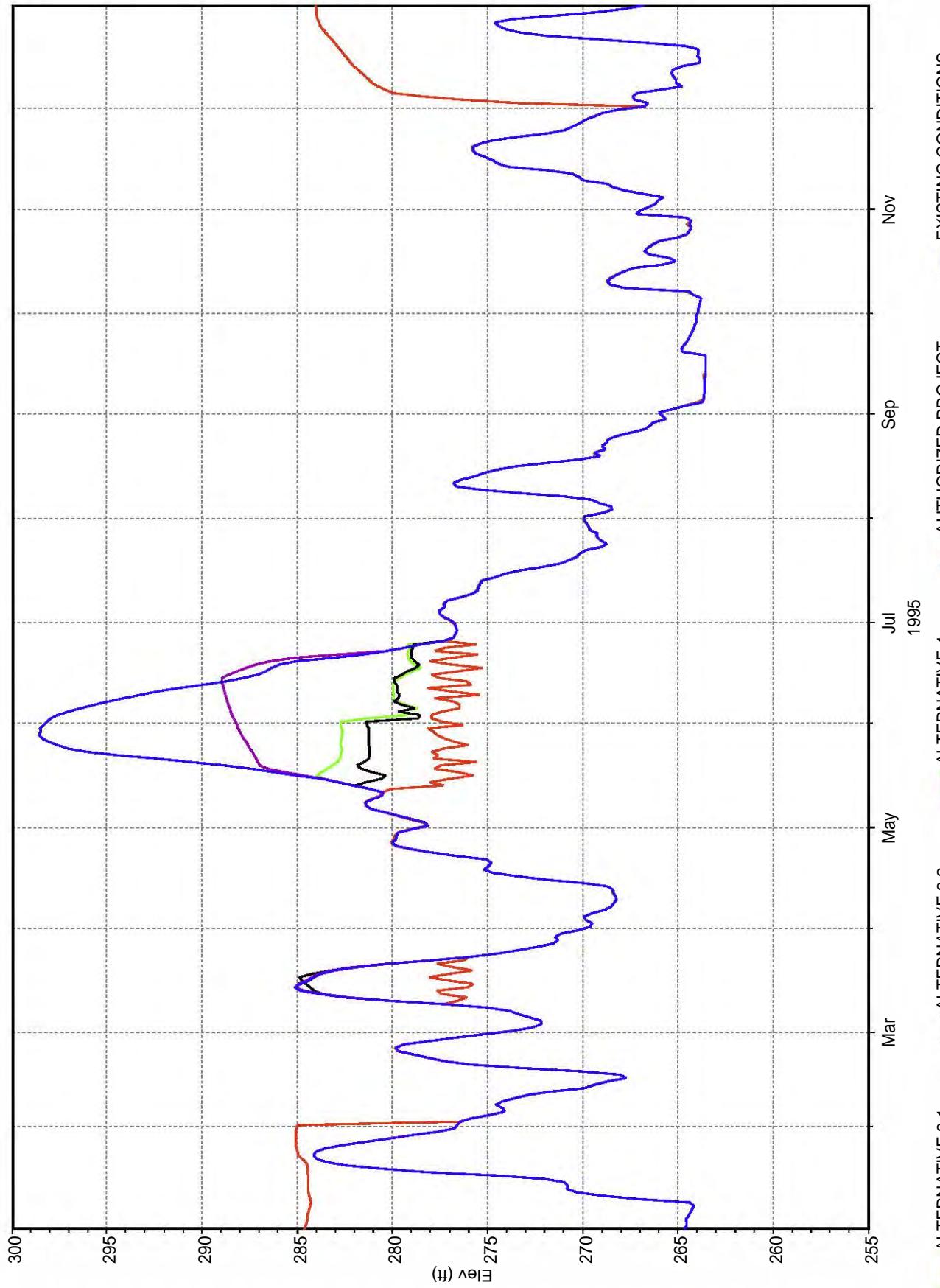








NEW MADRID FLOODWAY-INTERIOR POOL

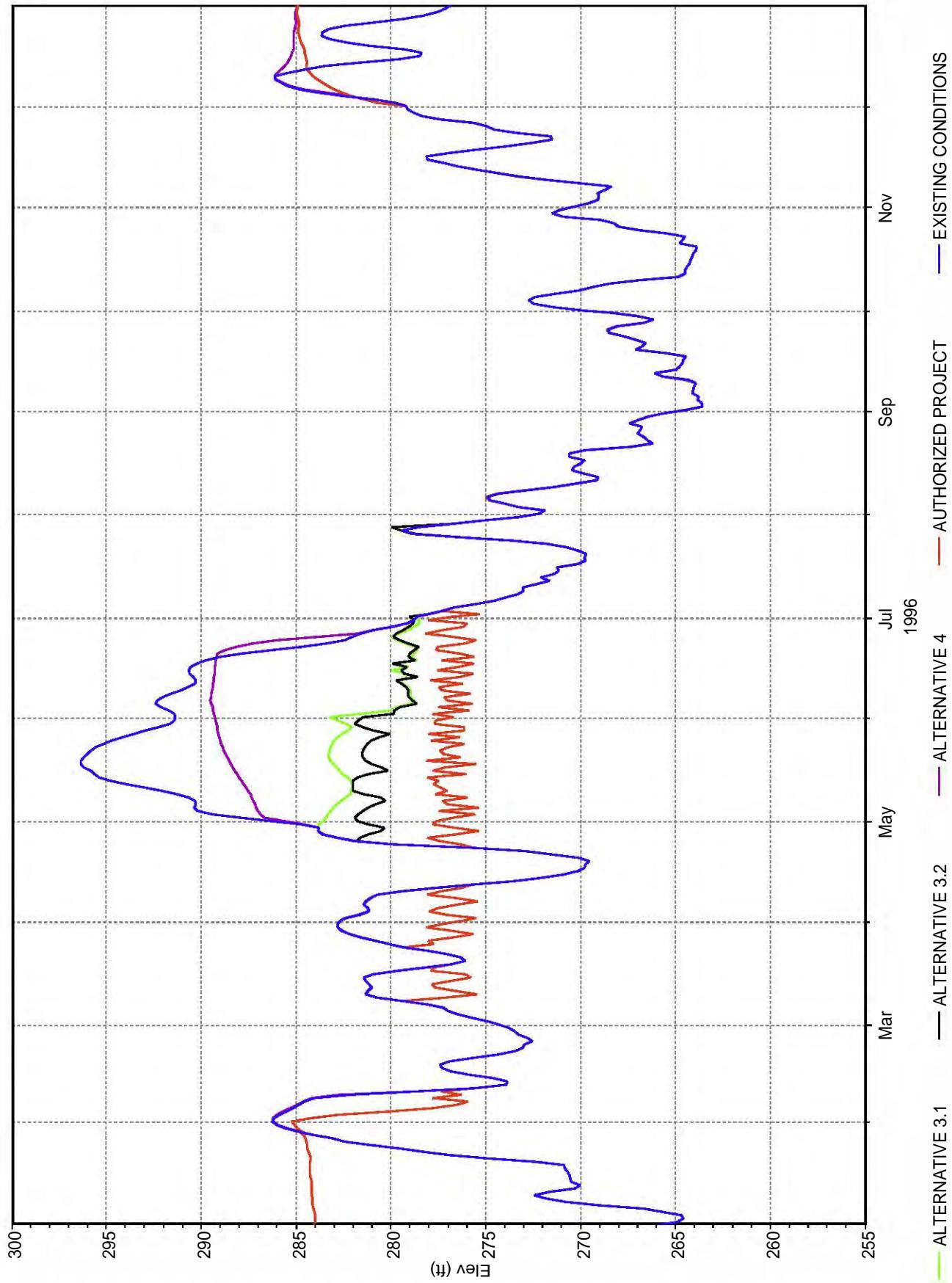


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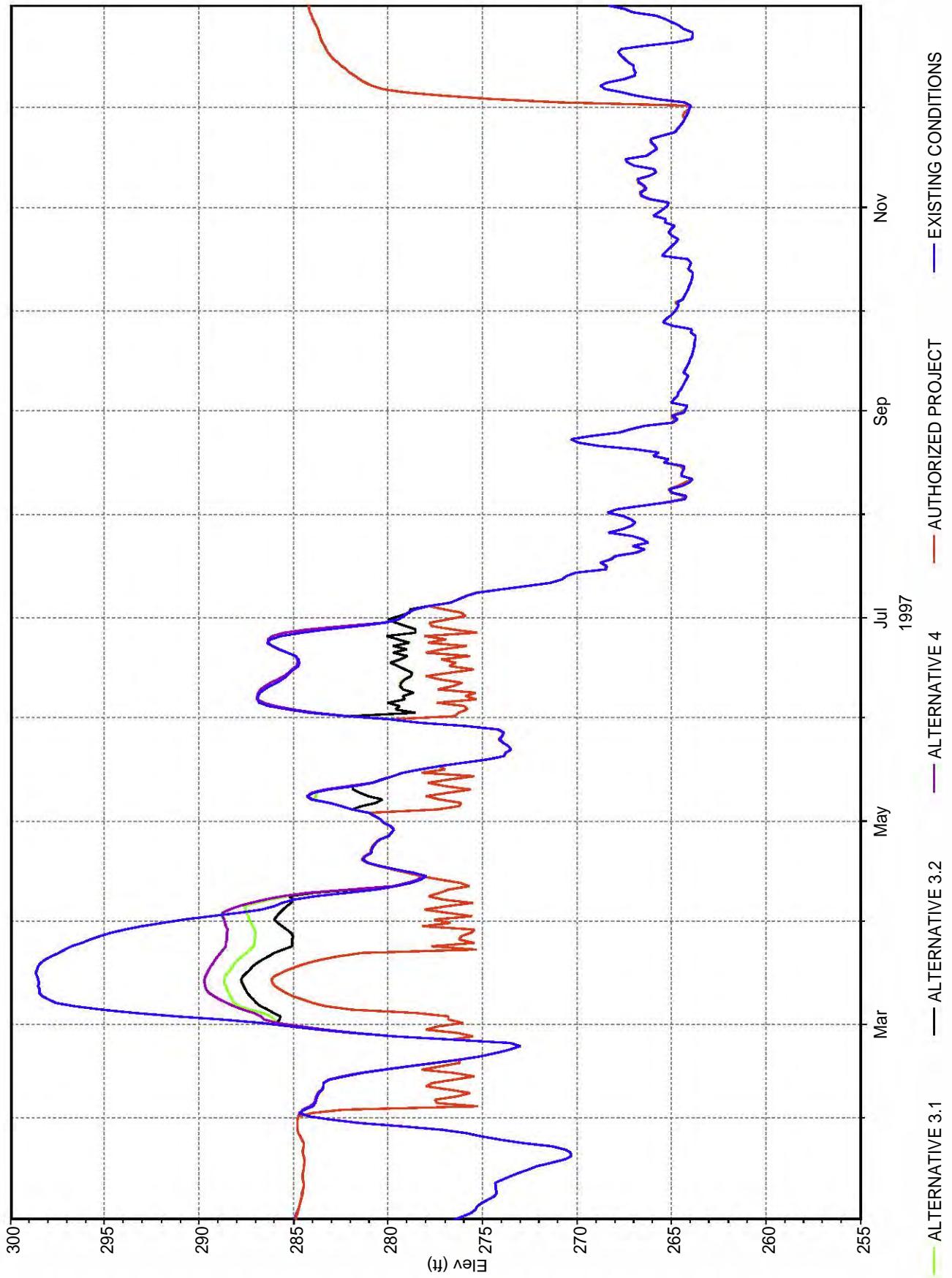
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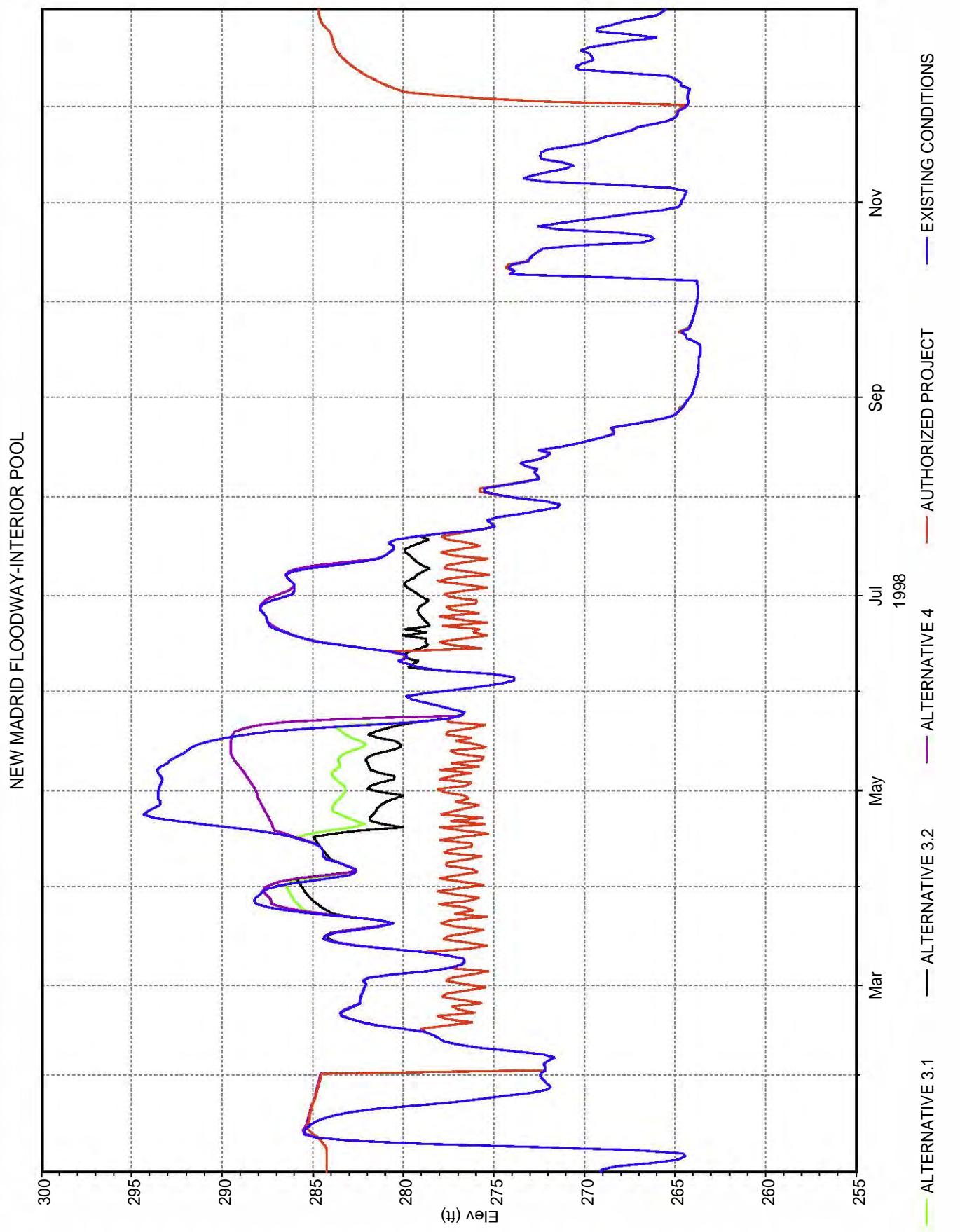
PLATE 126

NEW MADRID FLOODWAY-INTERIOR POOL



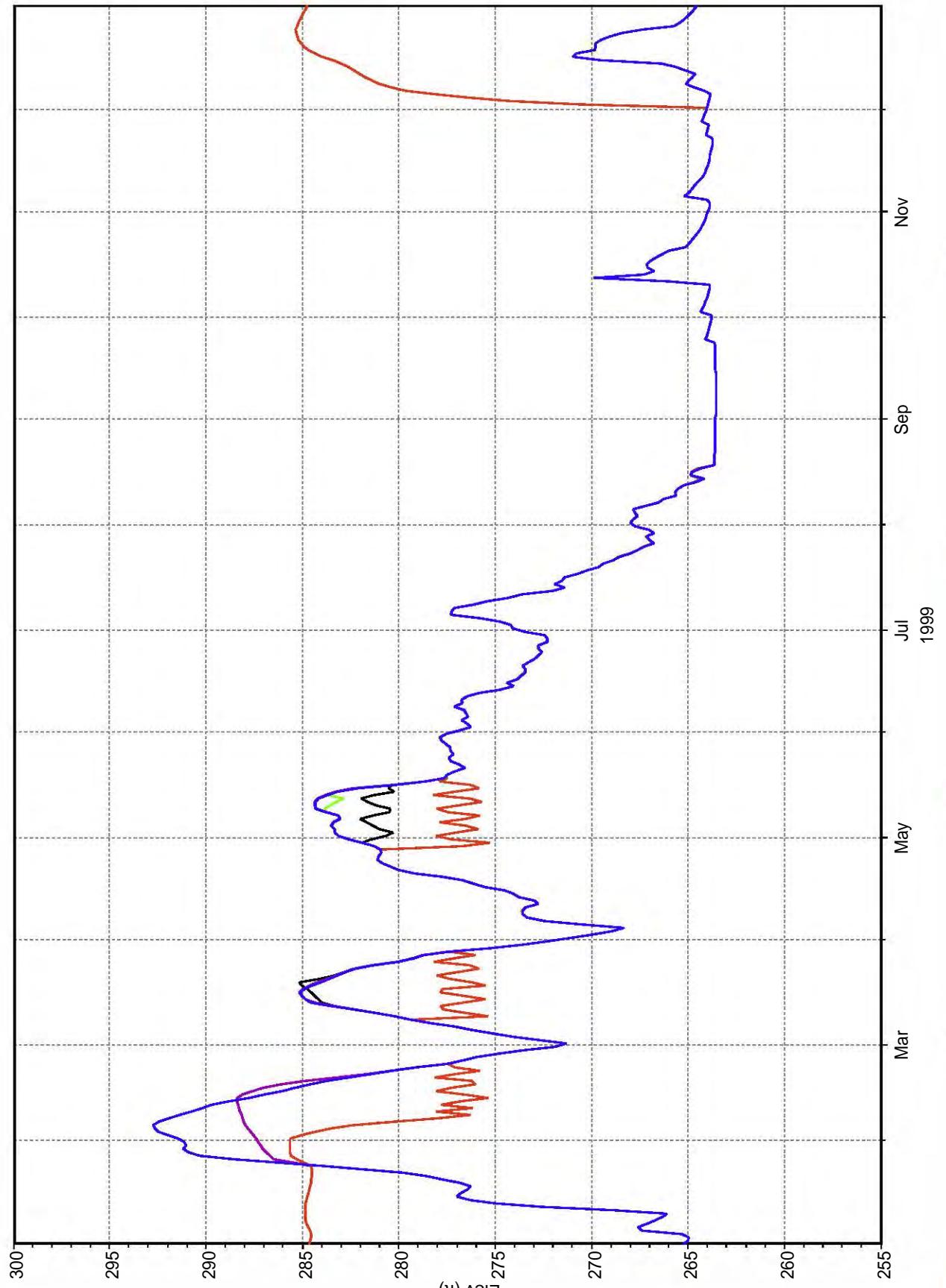
NEW MADRID FLOODWAY-INTERIOR POOL





C-149

NEW MADRID FLOODWAY-INTERIOR POOL

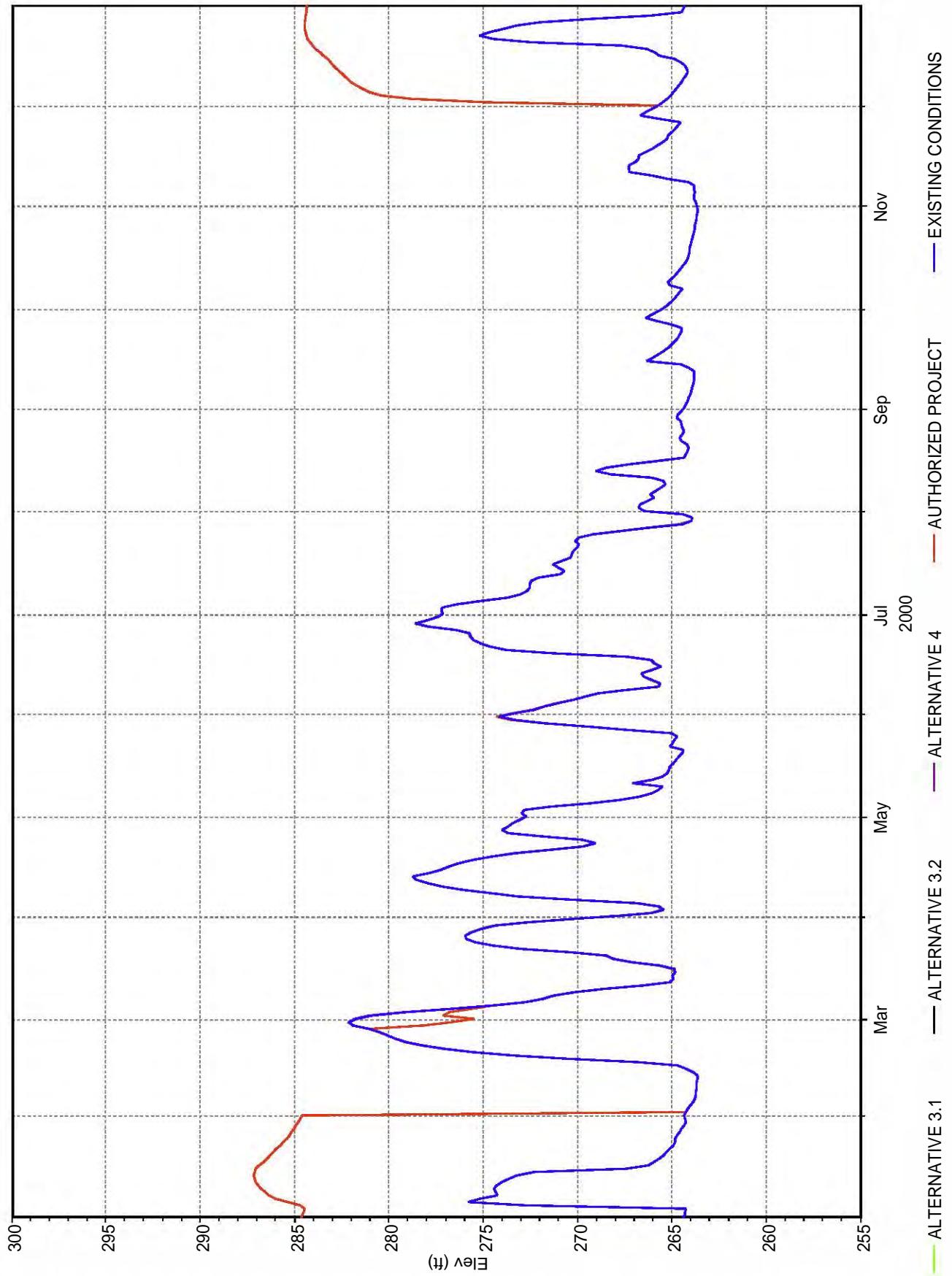


C-150

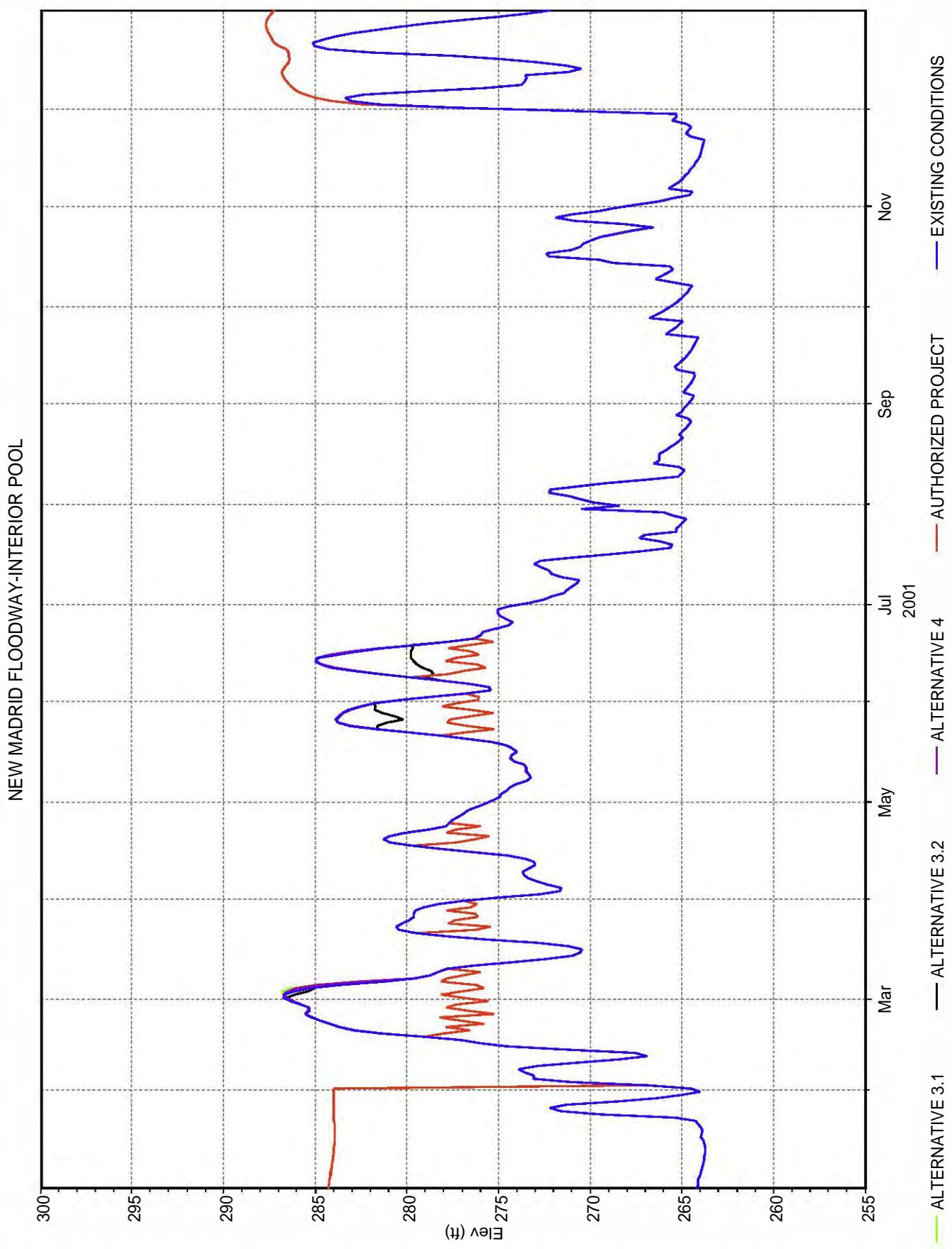
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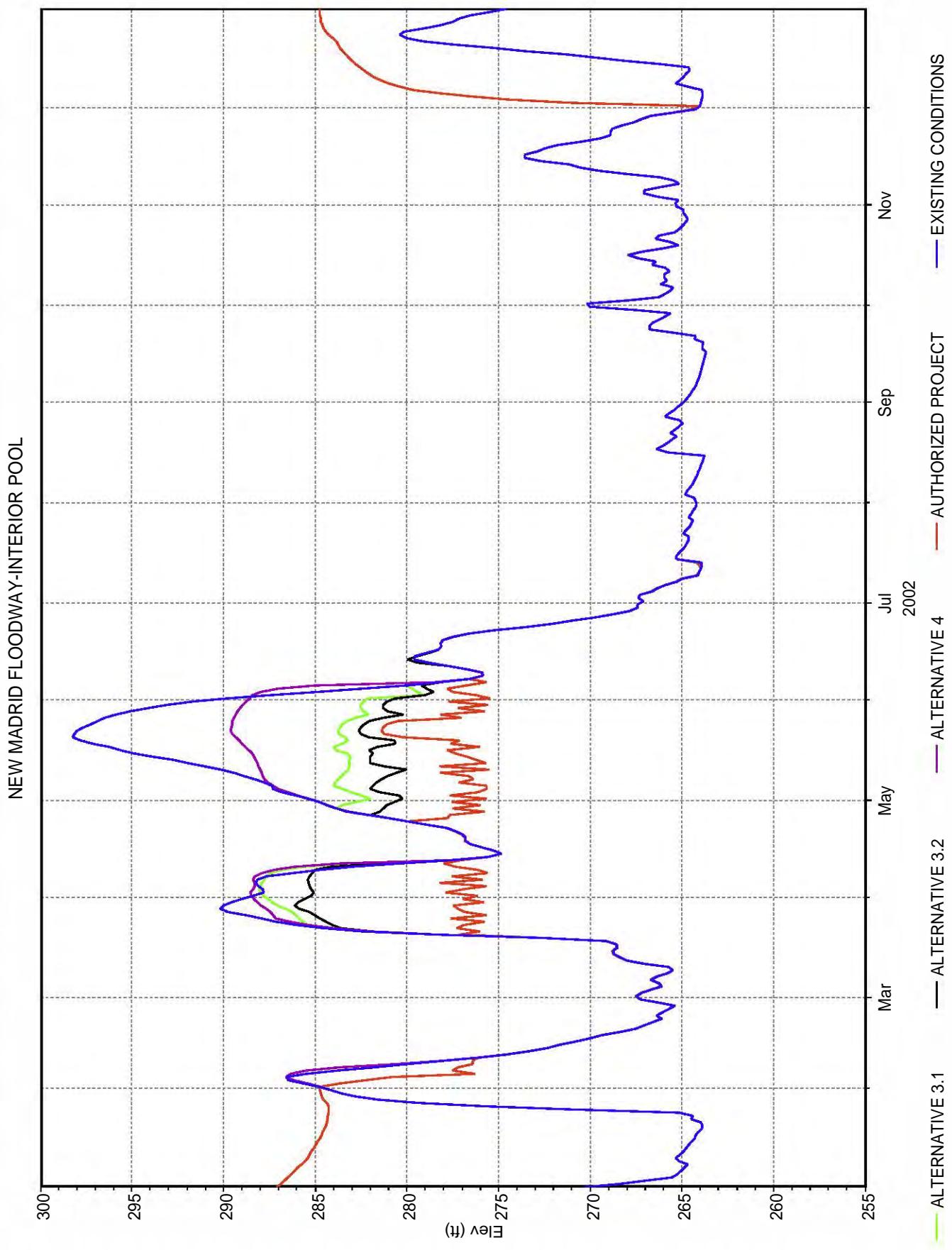
PLATE 130

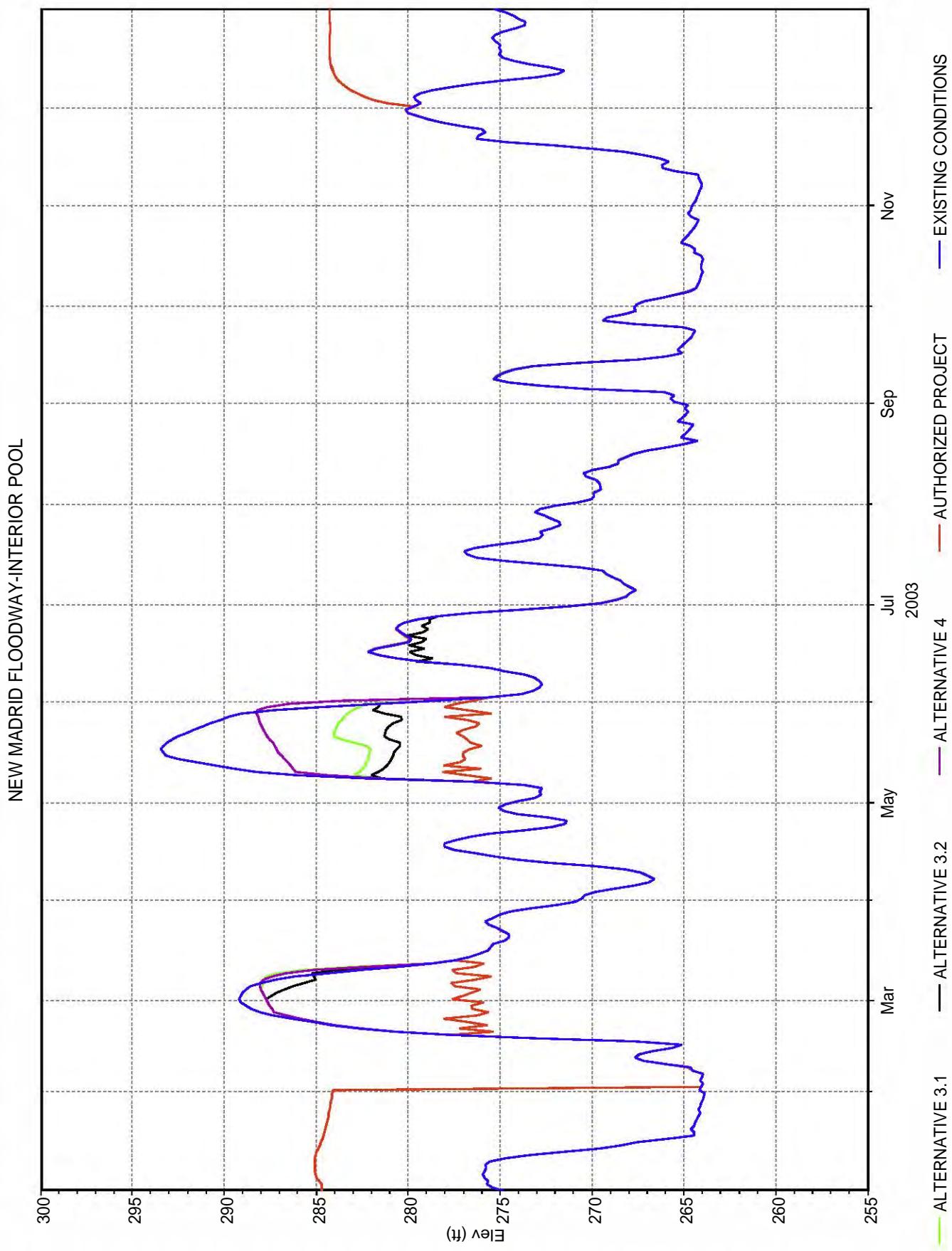
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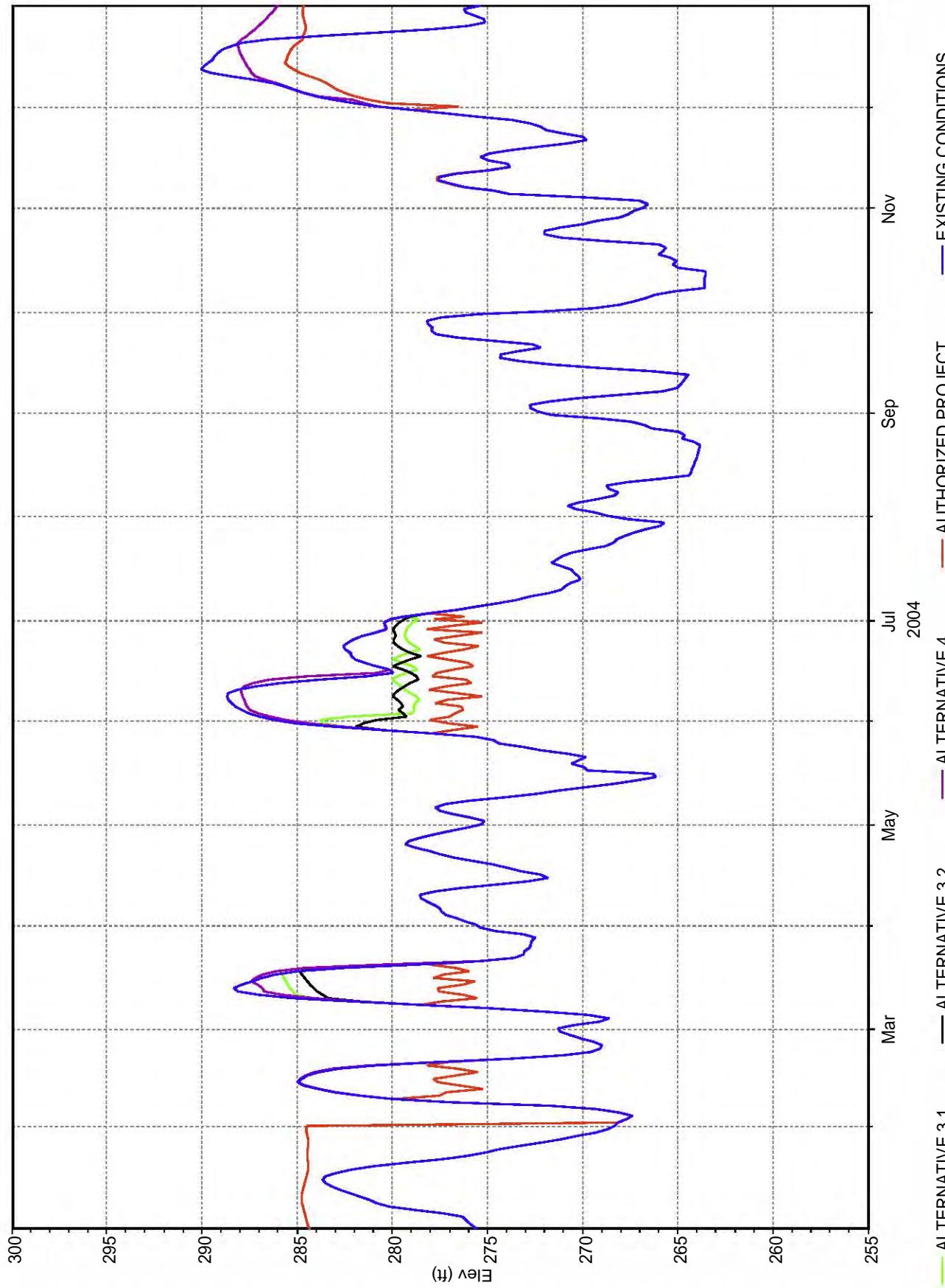
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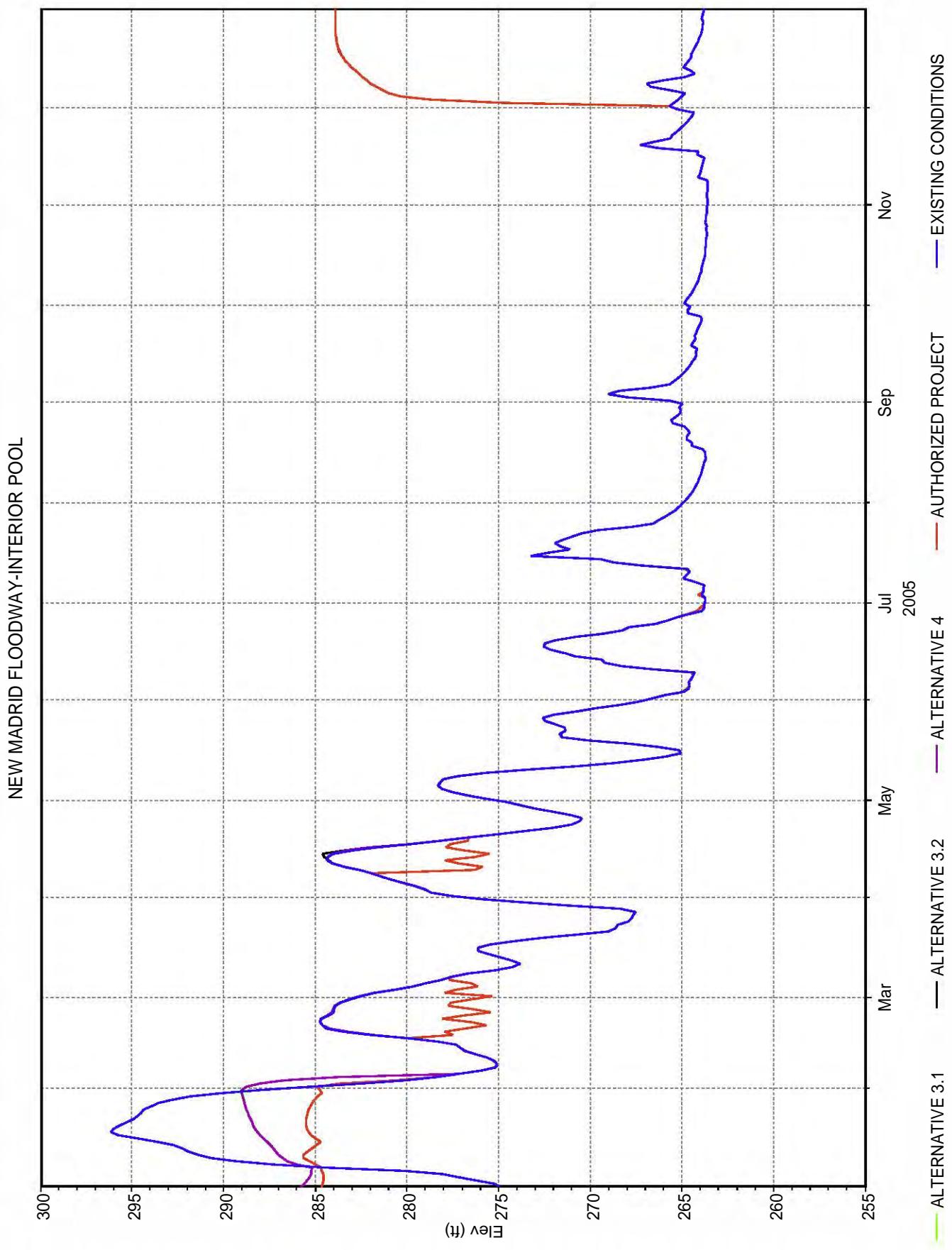




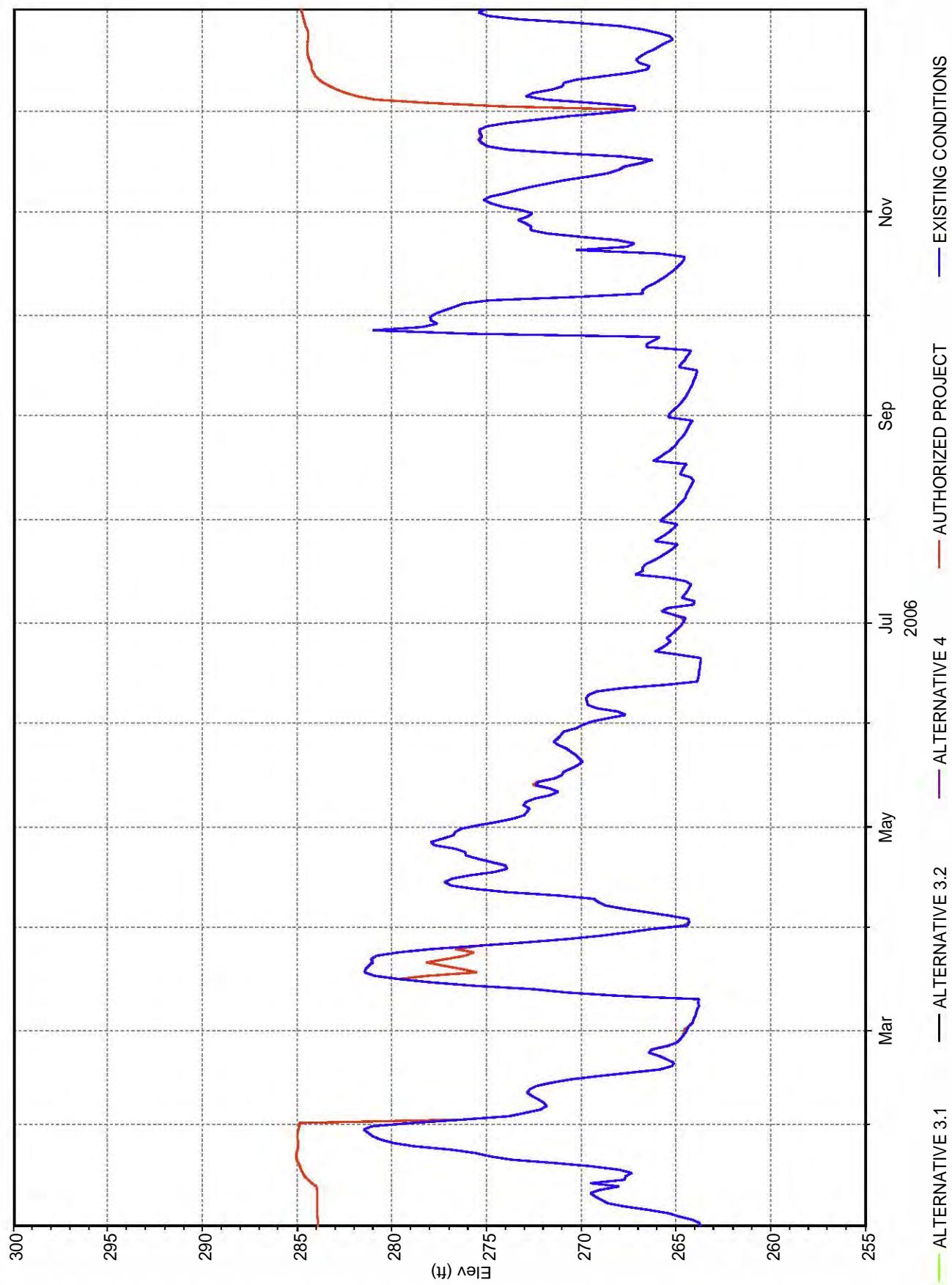
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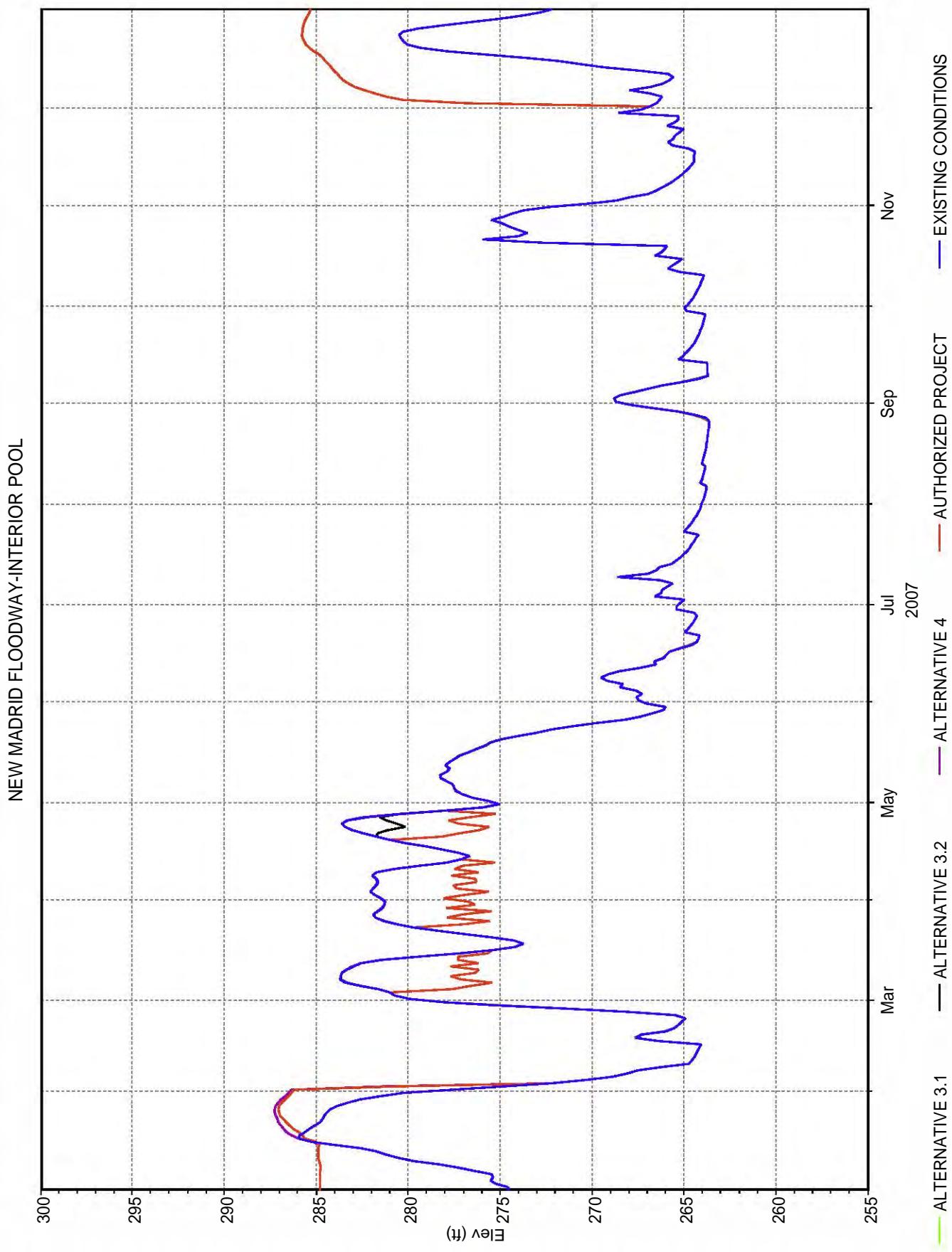


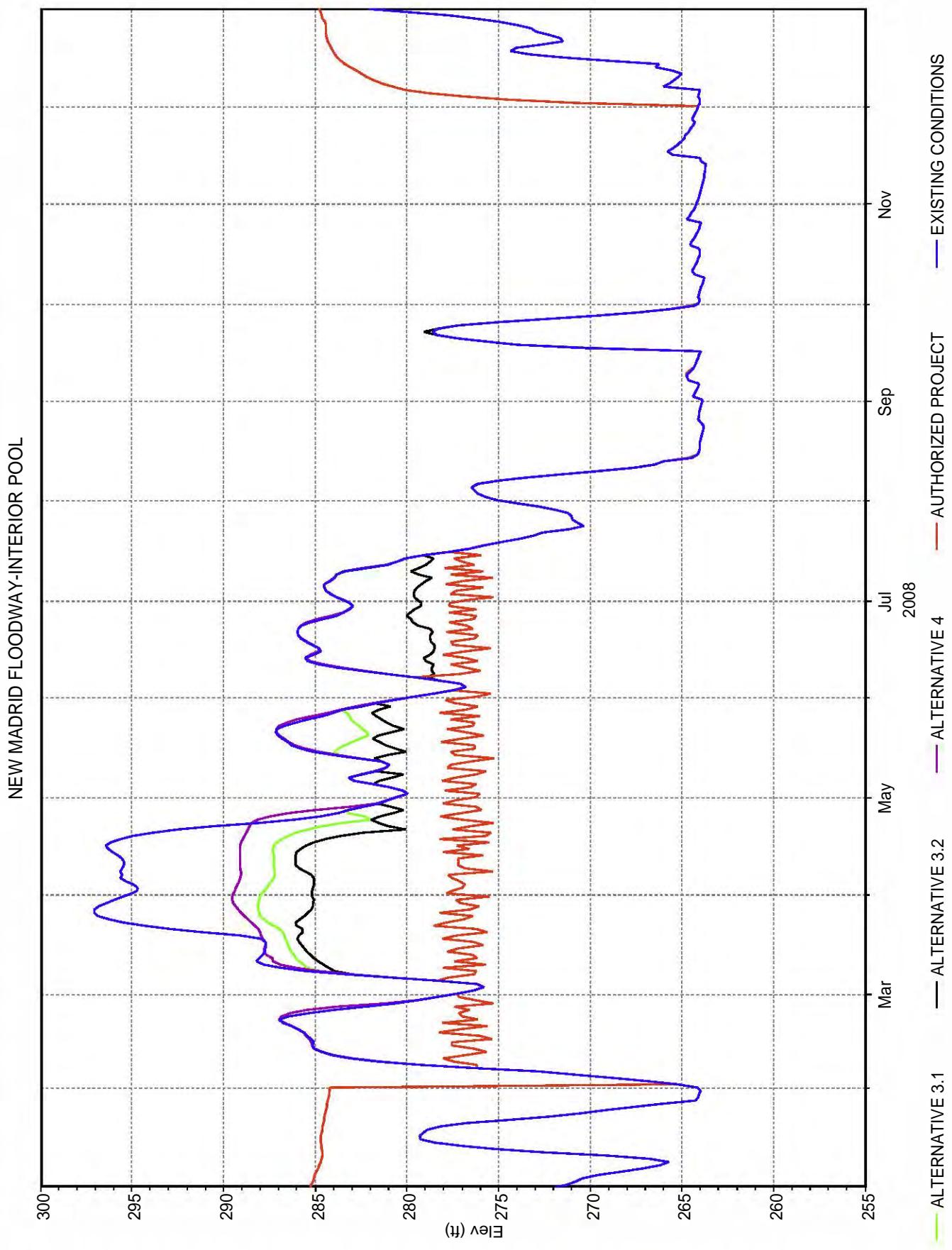
C-155

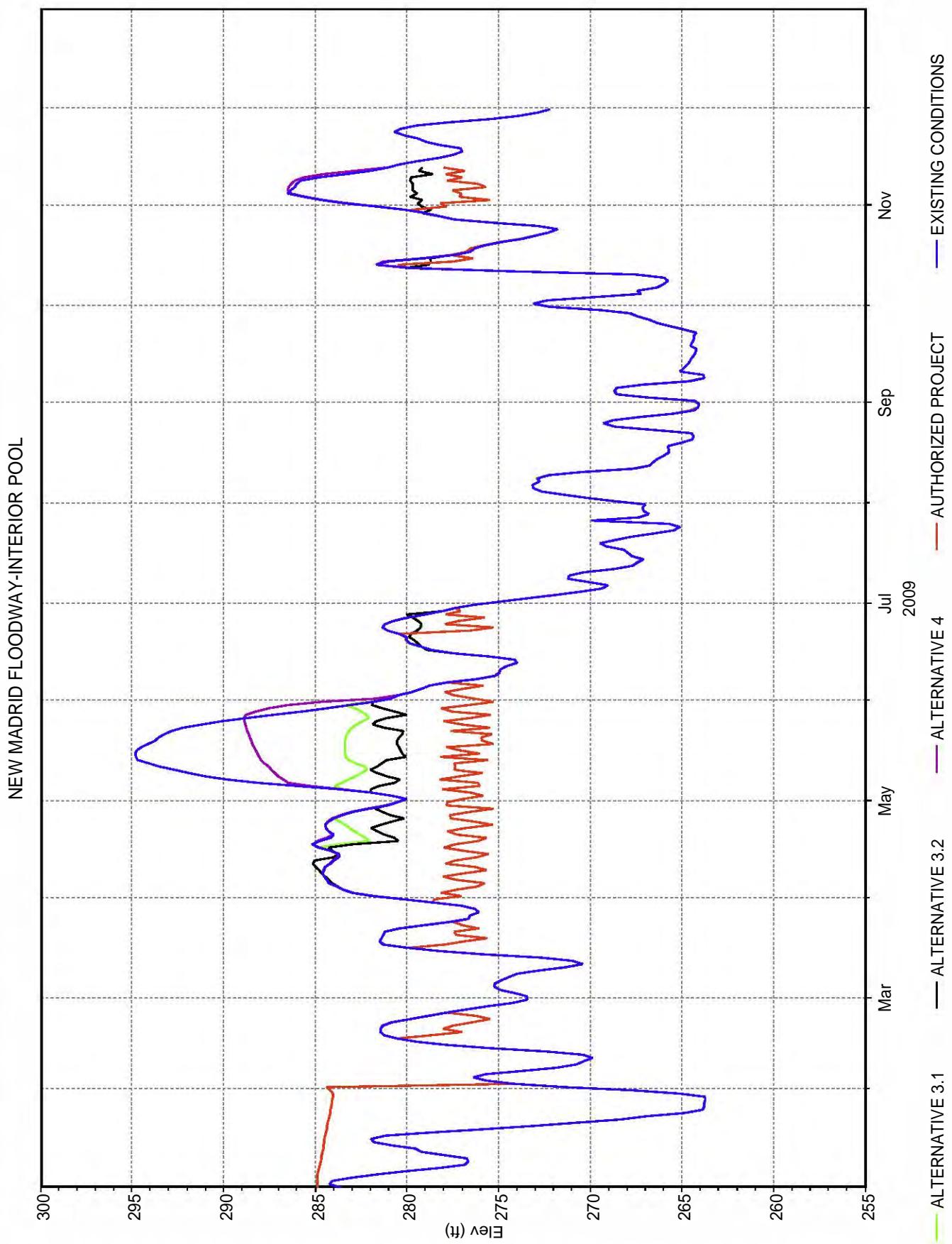


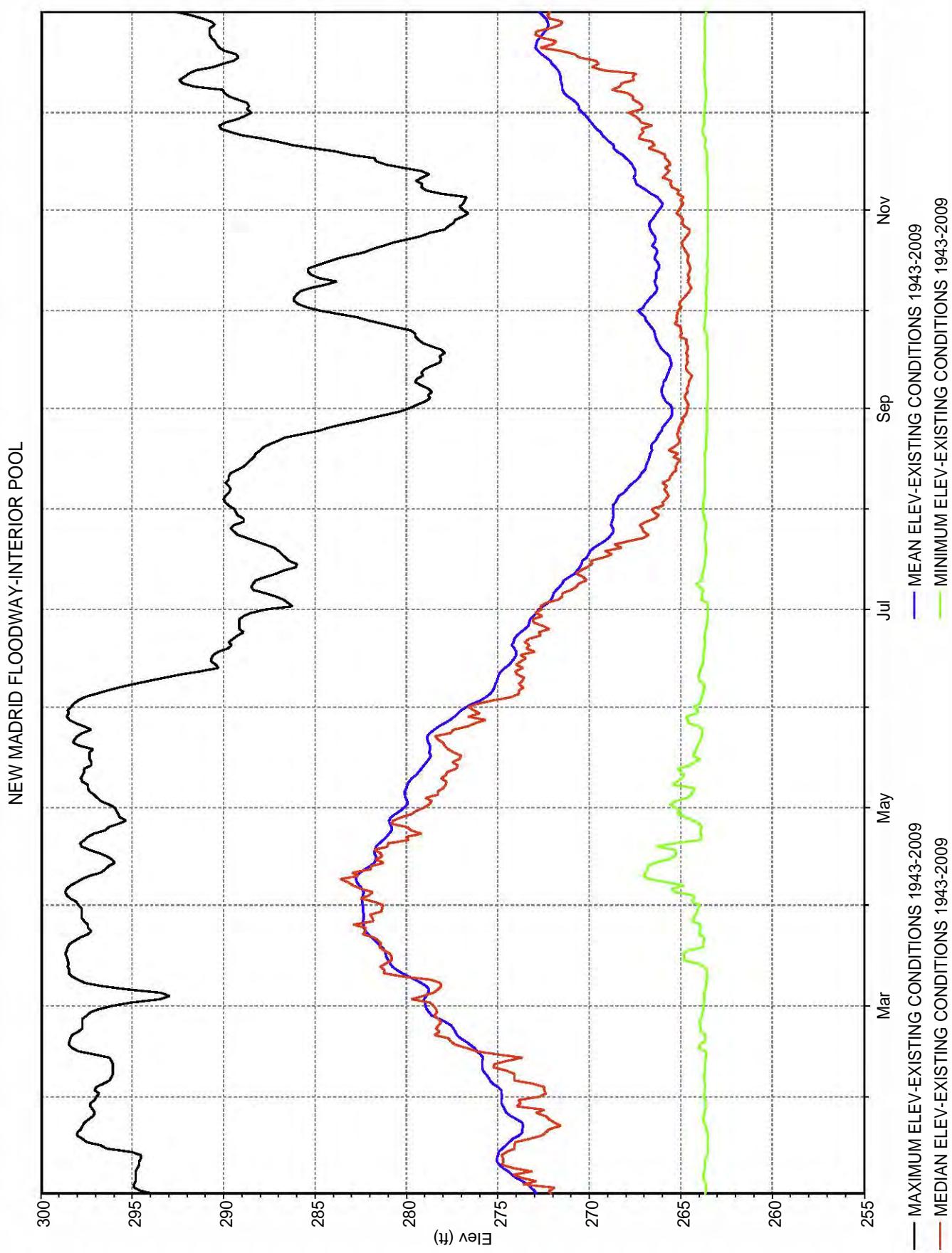
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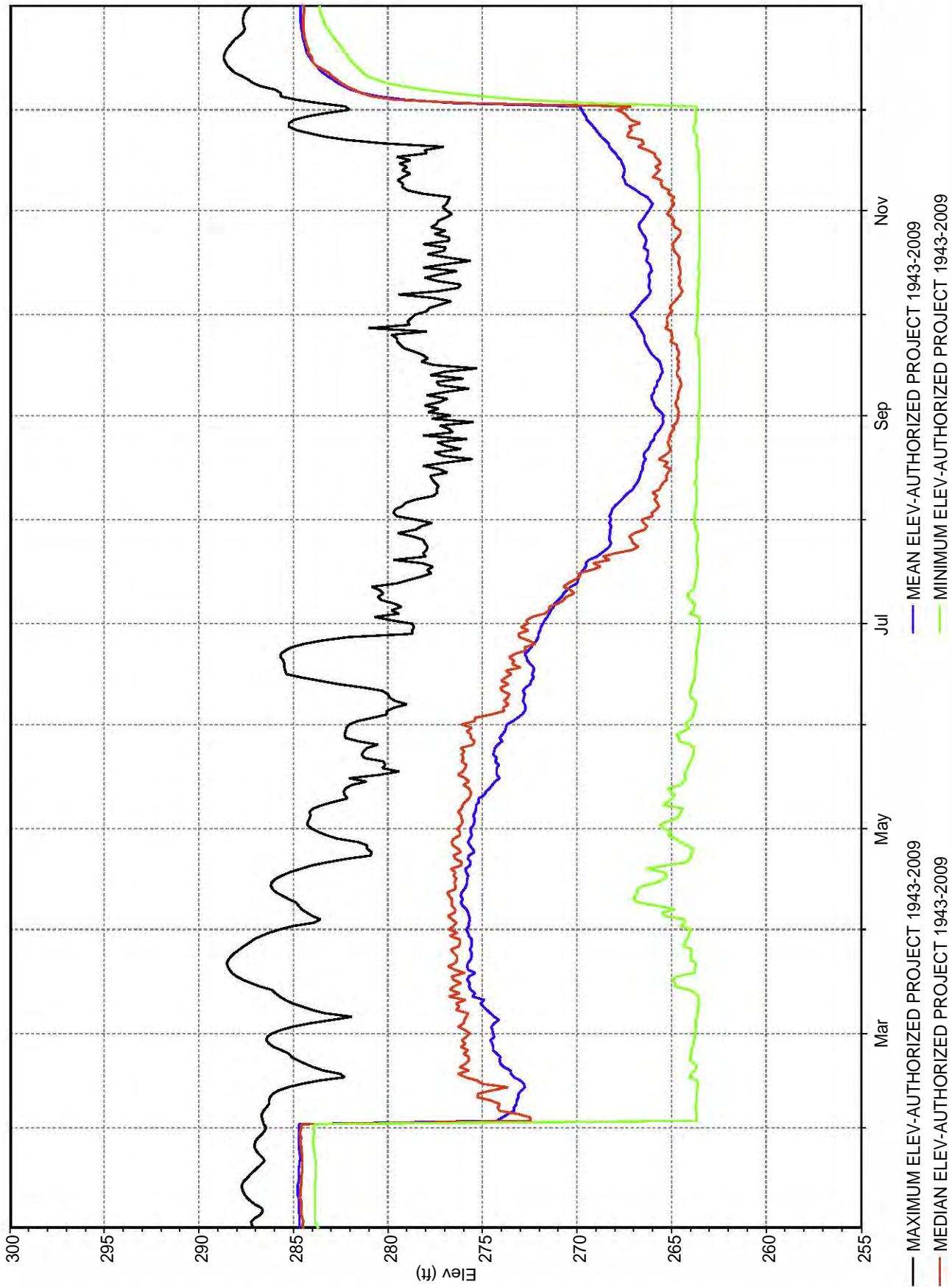




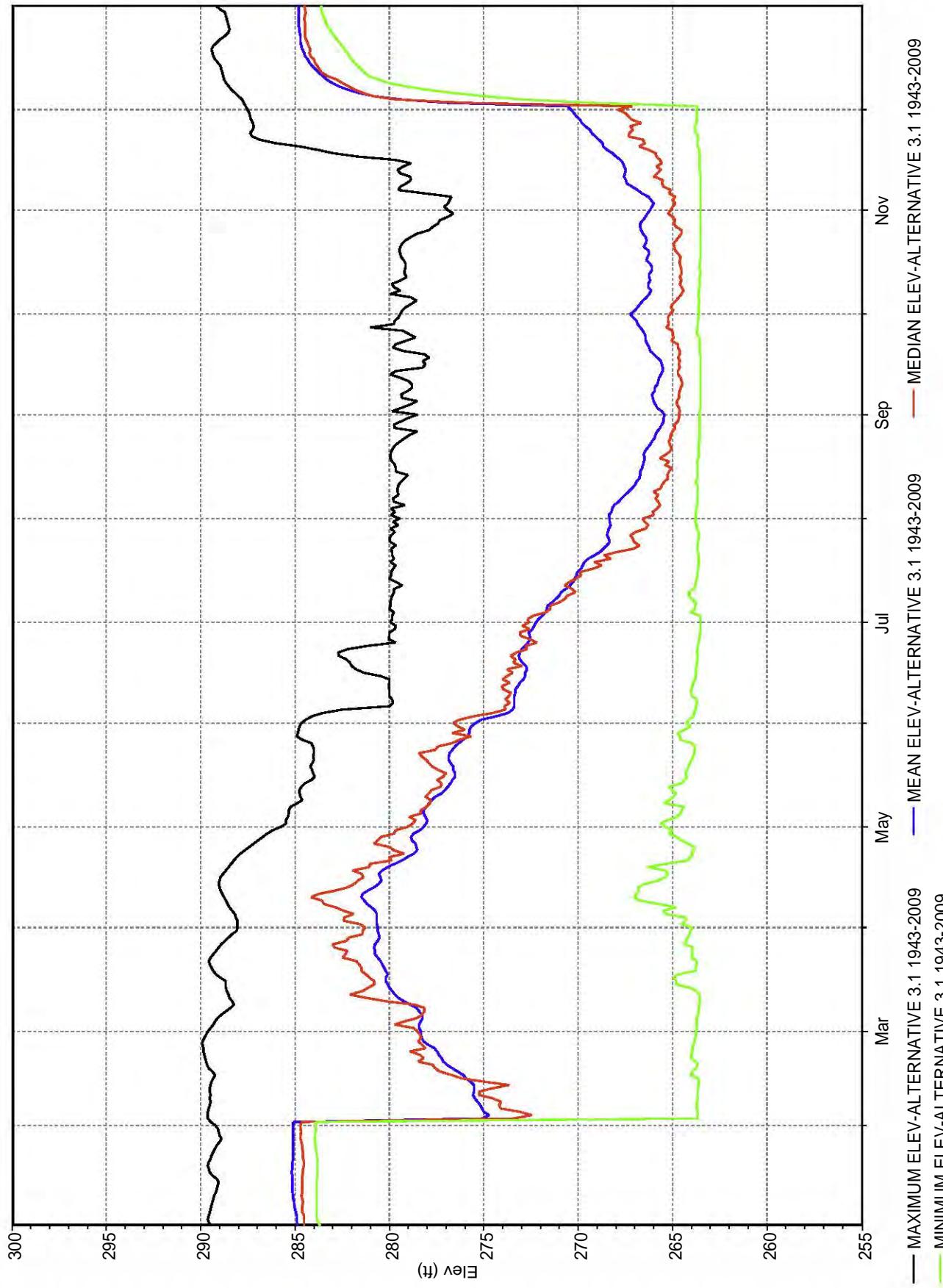




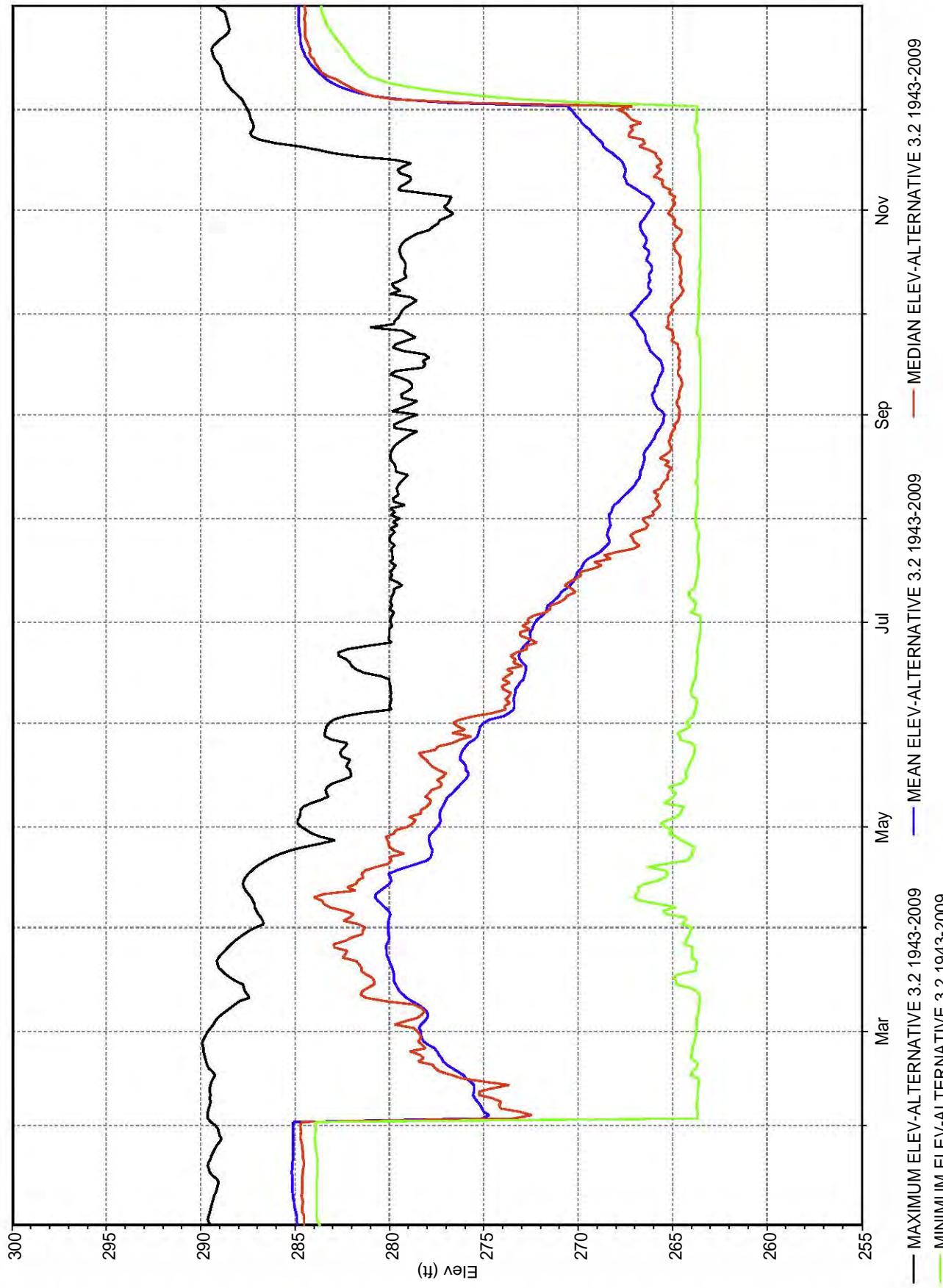
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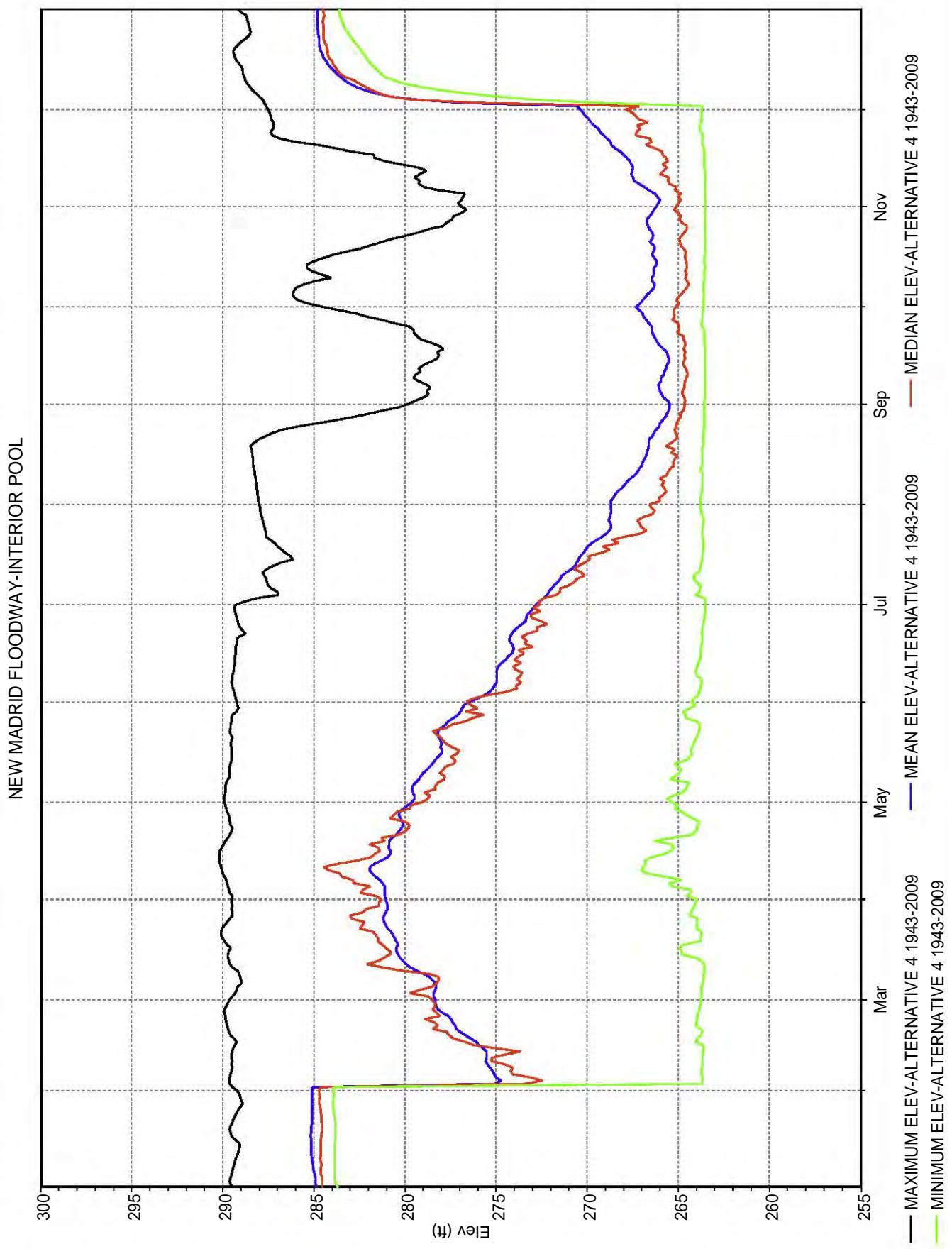


NEW MADRID FLOODWAY-INTERIOR POOL



NEW MADRID FLOODWAY-INTERIOR POOL





Appendix C

Part 2

Historical Rainfall-Runoff Analysis Using the Antecedent Precipitation Index



**U.S. Army Corps of Engineers
Memphis District**

HISTORICAL RAINFALL-RUNOFF ANALYSIS USING THE ANTECEDENT PRECIPITATION INDEX

By B. J. Doeing¹, M. ASCE, R. A. Gaines², and T. M. James²

Abstract

A long term simulation of rainfall-runoff can be used when analyzing the potential for economic benefits or flood damages to result from changes in the watershed, for developing discharge-frequency curves and establishing flow durations, and for applications in unsteady flow hydraulic models. This paper presents a method for computing historical synthetic discharge hydrographs. The procedure uses rainfall gage data, synthetic unit hydrographs, and the antecedent precipitation index (API) to account for regional rainfall losses. A computer program named "HUXRAIN" was developed by the Memphis District U.S. Army Corps of Engineers to simplify the procedure and to perform the analysis.

Introduction

The original HUXRAIN program was written by Robert Brittain of the Memphis District in 1972 as an offshoot to a rainfall runoff model written by Clinton Sumrall of the Lower Mississippi Valley Division. The HUXRAIN program was developed in order to produce period-of-record flow hydrographs in gaged or ungaged basins. Using hydraulic and hydrologic models for a basin, and calibrating these models to gages or historically derived data, period-of-record flow hydrographs can be developed with the program at any designated control point. The duration of the hydrograph simulation depends only on the length of rainfall records available or the study requirements.

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The program has been modified over the years during the transition from mainframe computers to the personal computers of today; however, the structure of the program has remained the same: read in period-of-record rainfall gage data, use a unique unit hydrograph at points where a synthetic flow hydrograph is desired, and use the antecedent precipitation index to account for total rainfall losses.

API - Surface Runoff Relation

The amount of surface runoff from a storm depends on the amount, intensity, and duration of rainfall and the soil moisture deficiency in the catchment at the beginning of the storm. Using rainfall and surface runoff data from gage records and an equation that relates API, precipitation, and time of year, a regional relationship between API and surface runoff was developed. The antecedent precipitation index is one of the more common methods used to account for rainfall loss rates. The rate at which moisture is depleted from a basin is roughly proportional to the soil saturation conditions. The soil moisture should decrease logarithmically with time during periods of no precipitation:

$$API_t = API_0 k^t \quad (1)$$

where API_0 is the initial value of antecedent-precipitation index, API_t is the reduced value t days later, and k is a recession factor ranging normally between 0.85 and 0.98 (Linsley et al 1975). To compute the API using rainfall data, the equation is rewritten to solve for API as a function of precipitation and time:

$$API = [(0.88^{t_1} PP_1) + (0.88^{t_2} PP_2) + \dots + (0.88^{t_{30}} PP_{30})] \quad (2)$$

where t is the number of days between the date of the API and the date of prior rains (denoted by subscript number), PP is the daily precipitation, and 0.88 is the value used for the coefficient k in the Memphis District. The correlation developed between API, time of year, rainfall depth, and surface runoff is shown graphically with coaxial curves in Figure 1. On the left side of the figure, a family of curves relate basin recharge and API for particular months of the year in the form of:

$$Y = A(2.0 - API)^2 + B \quad (3)$$

where Y represents basin recharge in inches, API is determined with equation (2), and A and B are numerical coefficients used to fit the curves. Basin recharge is the difference between measured rainfall and surface runoff and actually represents all rainfall losses, including evapotranspiration, infiltration, interception, and depression storage. The right side of the figure shows the relationship between rainfall, surface runoff, and recharge that follows from the curves developed on the left side of the figure. Since recharge is the common axis, runoff from a storm event can be

determined when the API is known, as illustrated by the path of the arrows shown in Figure 1.

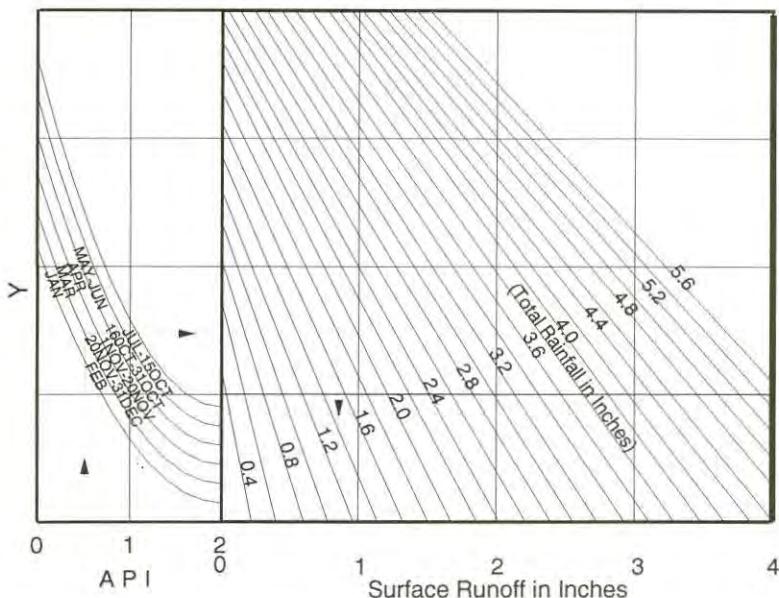


Figure 1. Correlation between API and Surface Runoff

Program Description and Application to Unsteady Flow Modeling.

Analysis of a stream network using an unsteady flow model, such as UNET, requires input of continuous discharge hydrographs throughout the watershed to describe flow at each tributary junction and runoff from intervening sub-basins (UNET 1992). The API methodology and the HUXRAIN program were used successfully to produce continuous hydrographs for an irrigation study in eastern Arkansas. The study area is a humid region where the average annual rainfall ranges from 48 to 52 inches. The procedure used to develop the hydrographs is described below.

In the first step, an HEC-1 model of the watershed was prepared. Although computer program HEC-1 will not yield a long-term hydrograph, runoff from a series of single rainfall events can be analyzed (HEC-1 1990). Partial duration rainfall depths for various return frequency storms were obtained from the National Oceanographic and Atmospheric Administration (NOAA) maps and used with the hypothetical storm option in HEC-1. Input values were estimated for initial and

uniform loss rates and single event discharge hydrographs were produced using Snyder's synthetic unit hydrograph method. The peak flow output for the return frequency flows in HEC-1 was compared to flow rates obtained using the USGS regional regression equations for the basin at selected node points. The loss rates were then adjusted in HEC-1 to produce peak flow output in closer agreement with the regression equation results.

Next, a rainfall data base spanning 24 years was compiled from National Climatic Data Center rain gage data obtained on CD-ROM (Hourly 1993). Gage station weights were based on Thiessen Polygons or similar techniques (Linsley et al 1975). The hourly rainfall data was converted to a 6-hour time base using computer program HEC-DSS (1990). Unit hydrographs with a time base of 6 hours were developed from the HEC-1 output at each point where continuous hydrographs were required. HUXRAIN utilizes a 6 or 24 hour rainfall database to determine the API, then applies the excess rain to unit hydrographs of the same duration to produce the simulated continuous hydrographs.

Having produced a synthetic flow gage of sufficient length of record to establish discharge-frequency relationships, the maximum yearly peak flows obtained from the HUXRAIN program were then evaluated in the flood frequency program HEC-FFA. Adjustments were made to the "A" and "B" coefficients in the API formula for basin recharge until discharge-frequency results agreed more closely with the previous HEC-1 results. After this step, HUXRAIN was executed for each node point, generating a continuous hydrograph and writing it to an HEC-DSS file (HEC 1990) for import to the UNET model. The UNET boundary conditions file was then created by specifying the appropriate DSS input file and path names for the lateral (tributary) and uniform lateral (intervening area) inflow hydrograph records throughout the watershed. The resulting UNET model simulates the combination and routing of all hydrographs along the study reach.

Application to Economic Analysis

Studies involving the analysis of proposed changes to a watershed can be facilitated with long term discharge hydrographs. Proposed changes include channel modifications, such as channel widening or realignment, construction of a dam or reservoir, or simply the removal of debris or bank vegetation from a channel. The changes in the watershed can be evaluated by comparing the impact of the proposed modifications to a baseline condition. In urban areas, economic impacts or benefits can be evaluated using standard discharge exceedence-frequency curves. Damages in urban areas generally occur when a structure is flooded, either partially or completely. However, impacts or benefits in agricultural areas are influenced more by flow duration and timing because damages depend on the time of year and the duration and extent of crop inundation.

Changes in flow duration between the base-line condition and the proposed condition can only be evaluated by comparing long-term discharge hydrographs

under both conditions. Baseline period-of-record discharge hydrographs can be obtained from stream gage records if available; however, ungaged basins or locations without a gage require developing a period-of-record hydrograph synthetically (Grigg 1985). As explained above, HUXRAIN can be used to produce the necessary hydrograph, or synthetic gage, from unit hydrographs obtained from HEC-1.

Economic evaluation of the proposed alternatives begins with the development of discharge exceedence-frequency values and flow and stage durations at the synthetic gages for both baseline and improved conditions. The stage-duration data is derived from flow-duration data and a stage-discharge curve at the gage. Agricultural benefits are accrued if the stage duration above bankfull stage is decreased for the improvement; damages are assessed if the duration increases. The question of whether an alternative is economically feasible (i.e. has a positive Benefit/Cost ratio) would be difficult to answer without stage-duration data and the time of year that bankfull stage is exceeded. These items cannot be accurately estimated without the synthetic gage period-of-record hydrographs.

Conclusions

Regional relationships have been determined by the Memphis District U.S. Army Corps of Engineers for the antecedent precipitation index (API), time of year, rainfall depth, and surface runoff. The District's computer program HUXRAIN uses these relationships with long-term rain gage data and unit hydrographs to develop continuous period-of-record discharge hydrographs. This type of long-term simulation has proven useful in analyzing economic benefits for proposed watershed changes in agricultural areas and for input into unsteady flow models.

References

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- Hourly Precipitation Data*. (1993). U.S. National Climatic Data Center, National Climactic Data Center, Asheville, NC.

Appendix H

Part 3

Model Test



**U.S. Army Corps of Engineers
Memphis District**

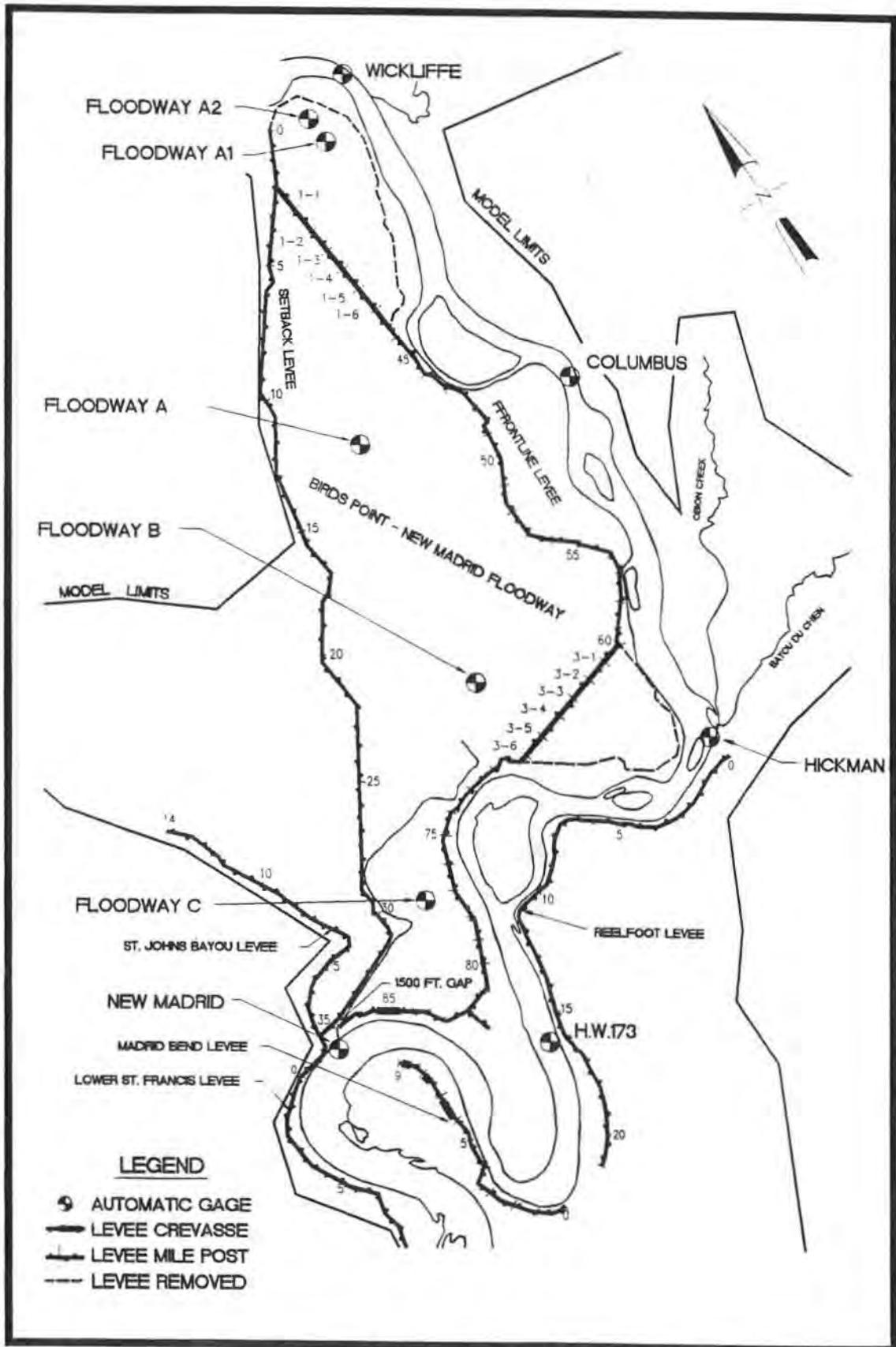


FIGURE 4. LEVEE ALIGNMENT - TEST 298 AND TEST 308

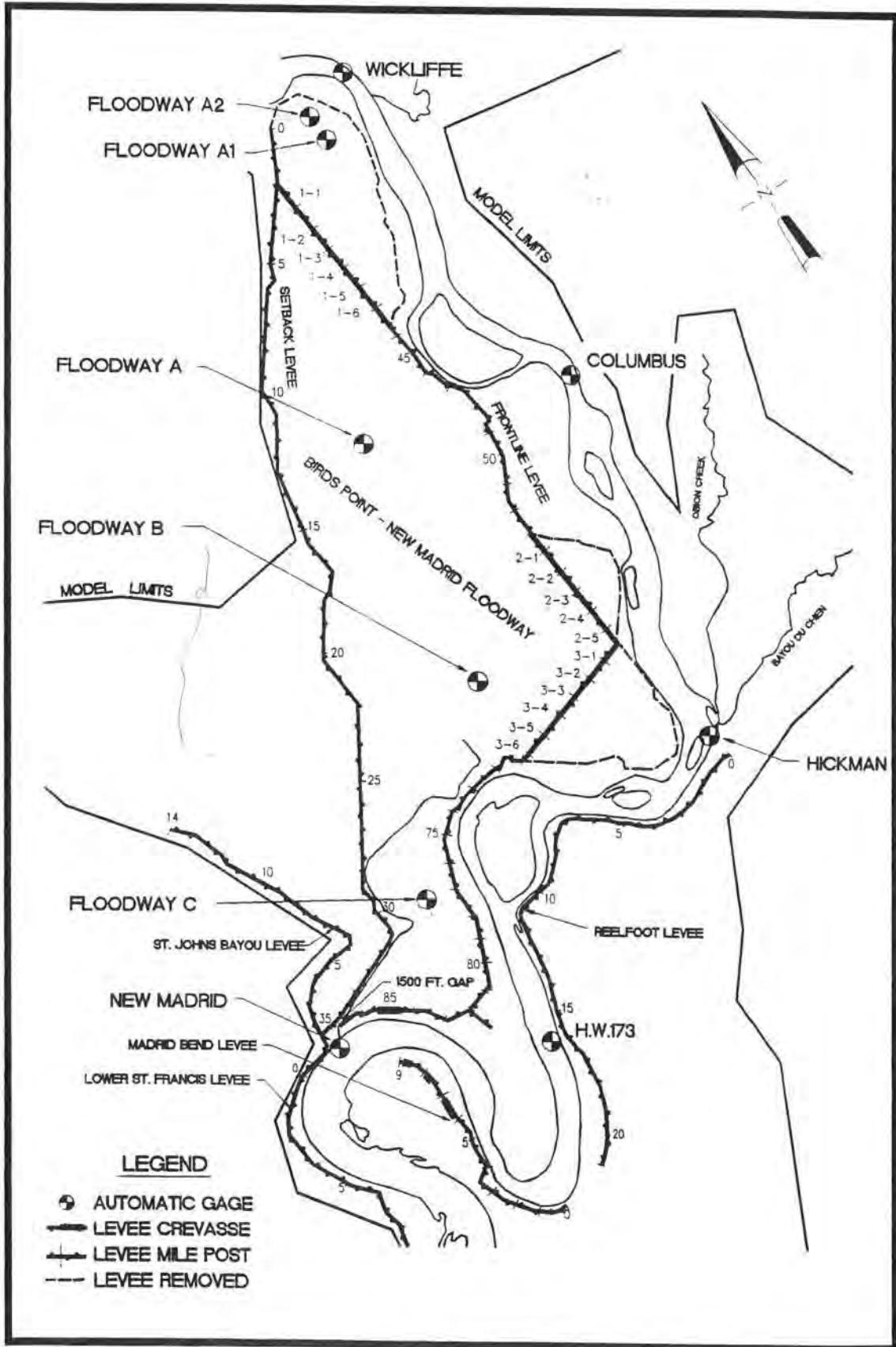


FIGURE 5. LEVEE ALIGNMENT - TEST 31S AND TEST 32S

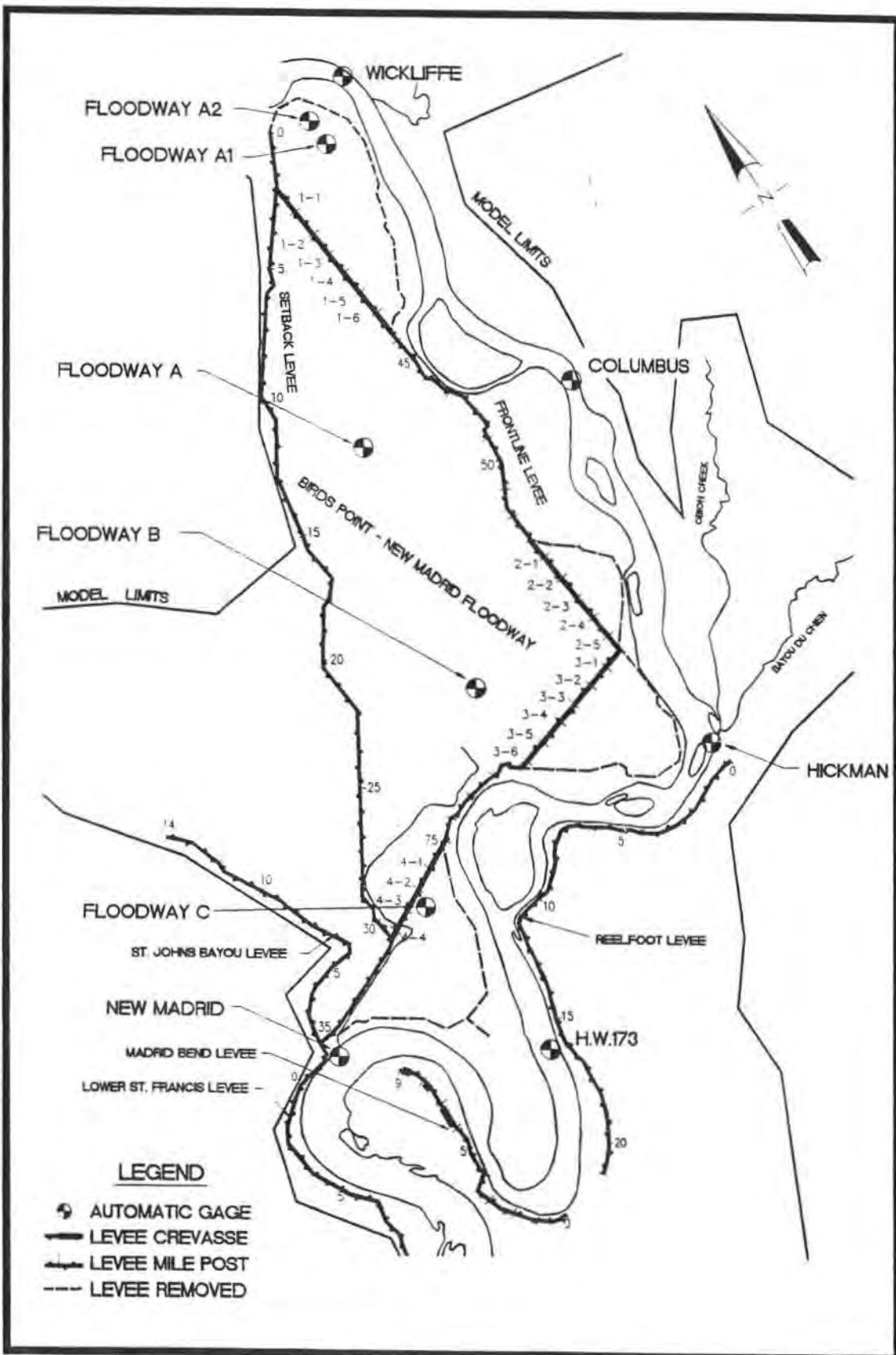


FIGURE 6: LEVEE ALIGNMENT - TEST 33S AND TEST 34S

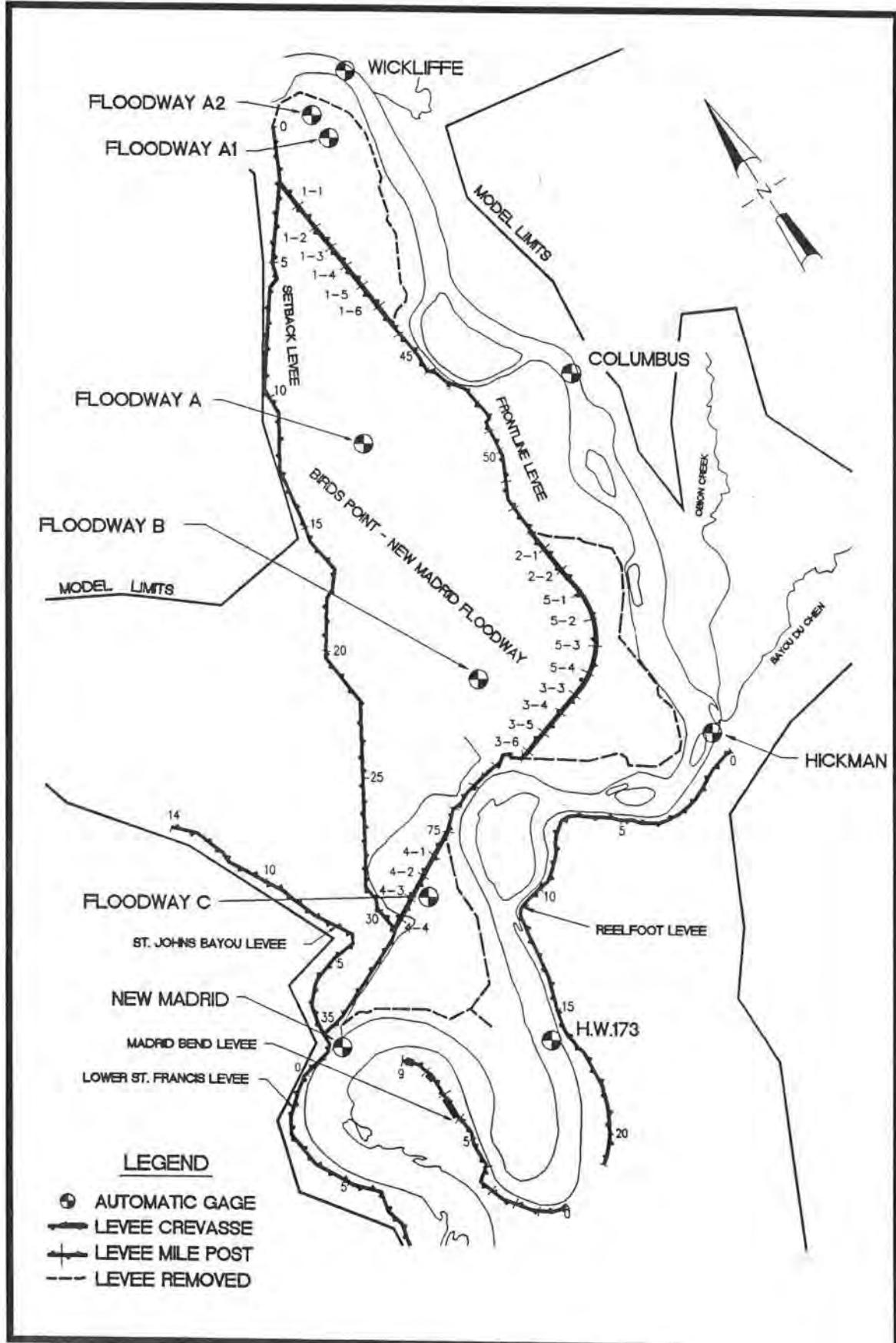


FIGURE 7. LEVEE ALIGNMENT - TEST 35S, TEST 36S AND TEST 37H

Appendix D

Part 1

St. Johns Bayou and New Madrid Floodway, Missouri Project History and Applicable Congressional Authorizations



**U.S. Army Corps of Engineers
Memphis District**

St. Johns Bayou and New Madrid Floodway, Missouri Project History and Applicable Congressional Authorizations

Prior to 1928

Large-scale flood protection and drainage enhancement within the project area began in 1847 when a Swampland Convention was held in Bloomfield, Missouri. Two years later, the New Madrid – Stoddard Canal Company was chartered but failed to progress. The Swamp Land Acts of 1849 and 1850 gave the states possession of unsold swamp and overflow lands bordering the Mississippi River. That Act provided that proceeds from the sale of the lands would be used to construct levees and drainage ditches. Congress designated 3,346,936 acres of unsold land in Missouri as Swamp Land and gave it to the state. An area-wide development plan lasted two years before the State of Missouri gave proceeds from the sale of these lands to the counties.

Mississippi County was a prime beneficiary of these land sales and soon had a large internal improvements fund. After the major flood of 1858, work began on the construction of a levee. Starting from Birds Point, Missouri, the county had constructed 30 miles of levee by the time the Civil War started. Agricultural development soon followed and attention turned to drainage in the early 1900s. Drainage ditches replaced the majority of natural systems and new drainage ways were constructed. Levee construction also continued. Prior to 1927, local interests constructed the New Madrid-Sikeston Ridge Levee for protection of the southwestern part of the project area from Mississippi River floods.

Flood Control Act of 1928

Following the Flood of 1927, Congress passed the Flood Control Act of 1928 that authorized the Mississippi River and Tributaries Project (MR&T). The MR&T provides a, “project for flood control of the Mississippi River in its alluvial valley and for its improvement from Head of Passes to Cape Girardeau, Missouri.”

The MR&T Project has four major elements: (1) levees and floodwalls to contain floods; (2) floodways to pass excess flows past critical Mississippi River reaches; (3) channel improvement and stabilization to provide efficient navigation; and (4) tributary basin improvements.

The Mississippi River Levee feature began construction in 1928 and continues today. Within the project area, the 1928 Flood Control Act authorized the raising and enlarging of the New Madrid-Sikeston Ridge Levee to provide protection against the project design flood¹. A 4,200-foot gap was left in the levee to provide an outlet for the St. Johns Bayou Basin. Although this gap provided an outlet, it also permitted Mississippi River backwater to inundate the lower St. Johns Bayou Basin.

¹ Although there is no assigned flood frequency, the project design flood has a peak discharge of 2,360,000 cfs at Cairo, Illinois. The project design flood is the most probable chance of producing the greatest discharge on the lower Mississippi River (Mississippi River Commission, 2009).

In addition to levees, the MR&T Project included the Birds Point-New Madrid Floodway. Completed in 1933, the Birds Point-New Madrid Floodway was designed to lower flood stages upstream and adjacent to the Floodway during major flood events. The 56-mile-long frontline levee had existed prior to the 1927 flood. Congress also adopted The Jadwin Plan, named for then Chief of Engineers Edgar Jadwin, which included two principal innovations: floodways to divert peak flows and reduce stages in the main channel; and a systems design approach based on a “project flood.” The Jadwin Plan states:

“The serious problem begins at Cairo at the confluence of the Ohio and the Mississippi. From here to New Madrid the main levee on the west bank chokes the river unduly and should be set back sufficiently to lower the head of water at Cairo by 6 feet in an extreme flood. The existing riverbank levee will be retained but lowered 5 feet. The Floodway between the new and the old levees will be capable of cultivation at all times excepting in floods greater than that of 1922.”

A 36-mile-long setback levee was constructed to a grade equivalent to 60.0 feet on the Cairo gage as planned. The frontline levee was retained and a section of it was to be degraded to an elevation equivalent to 55.0 feet on the Cairo gage; the remainder of the frontline levee would remain at an equivalent height of 57.0 feet on the Cairo Gage. The plan of operation was one of natural overtopping of the degraded section at an equivalent stage of 55.0 feet on the Cairo gage. Two gaps in the levee system were left, one at the St. Johns Bayou (4,200 feet in length) outlet and one at the Mud Ditch (1,500 feet in length) outlet. The purpose of these gaps was to provide drainage for the St. Johns Bayou Basin via St. Johns Bayou and the New Madrid Floodway via Mud Ditch. Although these gaps provided outlets for interior drainage, they also resulted in Mississippi River **backwater flooding** that inundated both basins.

Flood Control Act of 1946

The Flood Control Act of 1946 authorized the closure of the 4,200-foot gap in the St. Johns Bayou Basin. A levee was constructed across the gap and six 10-foot by 10-foot reinforced concrete culverts controlled by six power-operated lift gates at the outlet end were constructed across St. Johns Bayou Basin. Construction was completed in 1953.

Flood Control Act of 1954

The Flood Control Act of 1954 amended the Birds Point – New Madrid Floodway Project by authorizing modifications to the floodway in accordance with House Document Numbered 183 Eighty-third Congress. The House Document recommended the “construction of a new levee to project grade extending about 1,800 feet from the fuseplug section of the frontline levee across the existing gap therein to the setback levee, ... and the construction of a floodgate for the release of interior drainage.” (H.D. 183, 83D Congress, 1st Session).

The authorization was based on the Chief of Engineers' report dated 11 July 1952 that recommended closing the existing gap at the lower end of the New Madrid Floodway. The scope of the report was as follows:

2. *Scope* – This report of survey scope presents a plan for improved flood protection in the New Madrid Floodway, Missouri to be obtained by the closure of the existing gap in the frontline levee and construction of drainage improvements. Surveys consisting of cross sections, profiles, and borings at the closure site were utilized. Recent aerial photographs were used to delineate cultural development. The related office studies cover the physiographic, hydraulic, hydrologic, and other physical and economic aspects of the basin. Local drainage officials, the United States Fish and Wildlife Service, the United States Soil Conservation Service, and the Missouri Conservation Commission have been informed of the plan of improvement proposed herein.

The report concluded the following:

33. *Conclusion* – Present investigations of measures desired by local interests from the improvement of flood protection in the New Madrid Floodway lead to the conclusion that the continued availability of the floodway is necessary for the protection of Cairo, Ill., and no modification of the existing project for flood control [Mississippi River and Tributaries] relative to such operation is warranted at this time. The closure of the existing gap at the lower end of the floodway and construction of a floodgate to benefit 48,000 acres against overflow of floodway lands by backwater from Mississippi River floods is justified for construction by the United States at an estimated first cost of \$1,556,000 (September 1951), provided local interests furnish required cooperation.

The report concluded that the Floodway could be closed without jeopardizing the operation of the Birds Point-New Madrid Floodway during catastrophic floods. The amendment did not include plans for the construction of a pumping station; therefore, a **sump area** would be needed when the floodgate was closed due to high water on the Mississippi River. The **sump area** would have been comprised of approximately 26,000 acres of "unimproved land" in the backwater area. This was the majority of the land for which flowage rights had not been purchased. Because of the necessity of the large **sump area** and recently observed **impounded interior runoff** conditions on the adjacent St. Johns Bayou Basin with the recently completed flood control structure, the plan did not receive local support and local interests requested that construction be deferred until a pumping plant was authorized.

Flood Control Act of 1965

Further modification to the floodway was authorized by the Flood Control Act of October 1965, substantially as recommended by the report of the Chief of Engineers published in House Document 308, 88th Congress. This document authorized the raising of the frontline levee to give more protection to the floodway area, by

“raising the levees forming the east boundary of the Birds Point – New Madrid Floodway and modifying operation thereof to include breaching of the fuse plug levee during floods which reach 58 feet and threaten to exceed 60 feet at Cairo.”

Whereas the plan authorized by the 1928 Flood Control Act provided for operation of the floodway by overtopping a fuse plug levee when the river stage at Cairo reached 55 feet, the modified plan authorized by the 1965 Flood Control Act provided for artificial breaching of the fuse plug levee during floods which reach 58 feet and threaten to exceed 60 feet at Cairo. As a result of the modified plan of operation, modified flowage easements (based on artificial degradation of portions of the frontline levee) were purchased over lands above 300-foot National Geodetic Vertical Datum (NGVD). Original flowage easements had already been purchased for natural overtopping of the Floodway. The second purchase of flowage easements, modified flowage easements, was necessitated by the change in operation to artificial crevassing.

Congressional Resolutions, adopted 9 April 1965 and 2 February 1966

A report was prepared in 1974 in response to Congressional resolutions adopted 9 April 1965 and 2 February 1966 that stated,

“RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE, That the Chief of Engineers, United States Army, be, and is hereby requested to review the report on the New Madrid Floodway, Missouri, published as House Document Numbered 183, 83rd Congress, and other pertinent reports, with a view in determining whether any modifications of the recommendations contained therein are advisable at this time.”

“RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE, That the Chief of Engineers of the United States Army is hereby requested to review the report on the Mississippi River and Tributaries Project, published as House Document Numbered 308, Eighty-eighth Congress, and other pertinent reports, with a view in determining the advisability of modifying the recommendations contained therein, with particular reference to providing additional improvements, including pumping plants, in the St. Johns Bayou Basin, Missouri, in the interest of flood control and interior drainage.”

The Report of the Chief of Engineers, Department of the Army, dated 26 September 1975 included an Environmental Impact Statement titled *St. Johns Bayou and New Madrid Floodway Missouri* filed with the Council on Environmental Quality on 2 June 1976. The report recommended authorization and construction of the following:

1. A 2,000 cubic-feet per second (cfs) pumping station in conjunction with 64.2 miles of channel improvements in the St. Johns Bayou Basin area.

2. Channel cleanout on 5.8 miles of streams in Sikeston, Missouri.
3. Construction of a 500 cfs pumping station in the lower New Madrid Floodway.
4. Construction of a 500 cfs pumping station, an outlet structure with two power operated lift-gates at the outlet end, channel improvement on 11.0 miles of streams, and construction of 4.0 miles of new channel in the St. James Bayou area of the New Madrid Floodway.
5. The purchase of approximately 2,500 acres in Ten Mile Pond with appropriate water control structures for fish and wildlife management, use of easements to permit annual flooding on lowlands, and access for fishing in borrow areas to mitigate fish and wildlife losses which are expected to occur as a result of the project.

Water Resources Development Act of 1976

Section 101(a) of the Water Resources Development Act (WRDA) of 1976 authorized,

“The Secretary of the Army, acting through the Chief of Engineers, is hereby authorized to undertake the phase I design memorandum stage of advanced engineering and design of the following water resources development projects, substantially in accordance with, and subject to the conditions recommended by the Chief of Engineers in, the reports hereinafter designated.

Lower Mississippi River Basin

The project for flood protection for St. Johns Bayou Basin and New Madrid Floodway, Missouri: Report of the Chief of Engineers dated September 26, 1975, at an estimated cost of \$300,000.”

The General Design Memorandum and Supplemental EIS titled, *St. Johns Bayou – New Madrid Floodway: Mississippi, New Madrid, and Scott Counties, Missouri* recommended the following changes to the project²:

1. St. Johns Area. Channel improvements would be accomplished on 97.6 miles of stream in lieu of 64.2 miles. Channel cleanout would be on 21.2 miles instead of 5.8 miles as recommended previously. The pumping station size would be reduced from 2,000 cfs to a 1,000 cfs station.
2. New Madrid Floodway. The feasibility report recommended a split floodway plan which would have required construction of two 500-cfs pumping stations and

² Although this draft EIS supplements the 1976 Mississippi River and Tributaries project for the closure of the New Madrid Floodway and associated gate structure as well as the 1982 St. Johns Bayou and New Madrid Floodway SEIS for channel modifications and pumping stations, it does not supplement subsequent NEPA reports. This document constitutes the full, final, and only draft EIS for this project.

two gravity outlets. The plan recommended by the District Engineer in the Phase I study called for a combined floodway plan (*i.e.*, the existing drainage patterns are essentially unaltered) with one pumping station (1,500 cfs) and one gravity outlet (already authorized for construction by the 1954 Flood Control Act).

3. **Mitigation and Recreational Features.** Fish and wildlife features for mitigation of project impacts remained essentially unchanged from the feasibility report with the exception of proposed restrictive easements on areas used for disposal of dredged material along improved channels and a fish pool weir and bike/hike trail in Sikeston, Missouri.

Report of the Chief of Engineers dated 4 January 1983

The Chief's Report was submitted to the Secretary of the Army on 4 January 1983. The report contained the recommendations outlined in the General Design Memorandum. The Record of Decision was signed 5 January 1983.

Water Resources Development Act of 1986

The St. Johns Bayou Basin and New Madrid Floodway project was authorized for construction by the Water Resources Development Act of 1986, Section 401(a):

“(a) AUTHORIZATION OF CONSTRUCTION – The following works of improvement for the control of destructive floodwaters are adopted and authorized to be prosecuted by the Secretary substantially in accordance with the plans and subject to the conditions recommended in the respective reports designated in this subsection, except as otherwise provided in this subsection:

St. Johns Bayou Basin and New Madrid Floodway, Missouri

The project for flood control, St. Johns Bayou Basin and New Madrid Floodway, Missouri: Report of the Chief of Engineers, dated January 4, 1983, at a total cost of \$112,000,000, with an estimated first Federal cost of \$78,500,000 and an estimated first non-Federal cost of \$33,500,000, except that the land for mitigation of damages to fish and wildlife shall be acquired as soon as possible from available funds, including the Environmental Protection and Mitigation Fund established by Section 908 of the Act, and except that lands acquired by the State of Missouri after January 1, 1982, for mitigation of damage of fish and wildlife within the Ten Mile Pond mitigation area shall be counted as part of the total quantity of mitigation lands required for the project and shall be maintained by such State for such purpose.”

The project was not immediately constructed because the local sponsor could not meet cost-sharing requirements also enacted by WRDA 1986. Therefore, construction was deferred until the local sponsor could obtain funding.

East Prairie, Missouri Enterprise Community

President Clinton designated East Prairie, Missouri, as an Enterprise Community (EC) in December 1994. The EC designation is designed to create self-sustaining long-term economic development in areas of pervasive poverty, unemployment, and general distress through the development and implementation of strategic plans that allow them to reach their full economic potential. A \$2.95 million grant was awarded to East Prairie based on its strategic plan. Its plan was framed around the key principles of economic opportunity, sustainable community development, community based partnerships, and a strategic vision for change. In addition to the \$2.95 million that was provided to the city for use towards local economic initiatives, the EC designation included the reduction of the local share of project costs to a level commensurate with the depressed economic conditions in the area (from 35 percent to 5 percent). The EC program is administered by the U.S. Department of Agriculture (USDA). USDA has pledged to provide the necessary funds required to reduce the local sponsor's costs to 5 percent (not including the \$2.95 million grant).

Water Resources Development Act of 1996

Congress facilitated the participation of USDA in project implementation by including language in Section 331 of WRDA 1996 to provide a statutory basis for using USDA funds to supplement local project funding capabilities, as follows:

“Notwithstanding any other provisions of law, Federal assistance made available under the rural enterprise zone program of the Department of Agriculture may be used toward payment of the non-Federal share of the costs of the project for flood control, St. Johns Bayou Basin and New Madrid Floodway, Missouri, authorized by Section 401(a) of the Water Resources Development Act of 1986 (100 Stat. 4118).”

1997 Limited Reevaluation Report

A Limited Reevaluation Report (LRR) of selected features of the overall authorized project that offer the most immediate benefits to East Prairie and vicinity was conducted in 1997. The LRR focused on updating economic analysis and environmental documentation for those project features associated with the initial phase of the project (*i.e.*, Phase 1).

Recommended Phase 1 project features included 4.5 miles of channel enlargement of St. Johns Bayou, 8.1 miles of channel enlargement of Setback Levee Ditch, 4.3 miles of vegetative clearing of Setback Levee Ditch, 10.8 miles of channel enlargement of St. James Ditch, a 1,000 cfs pumping station along St. Johns Bayou, and a 1,500 cfs pumping station in conjunction with the separately authorized New Madrid Floodway closure. Approximately 413 acres of the originally authorized 2,500 acres of land would be required to mitigate impacts of the Phase 1 portion of the project. In addition to compensatory mitigation, the selected plan included the potential to flood up to 5,700 acres of lands during waterfowl season.

The first item of work consisting of the 4.3 miles of vegetative clearing along Setback Levee Ditch was completed.

During the development of the LRR and based on concerns expressed by other governmental agencies, USACE made the determination to supplement the EIS for the project. In addition to documenting the effects of the St. Johns Bayou Basin and New Madrid Floodway project, the additional supplement would analyze the effects of constructing the mainline levee closure authorized by the Flood Control Act of 1954.

2000 Supplemental Environmental Impact Statement

A Supplemental Environmental Impact Statement (SEIS) titled, *Flood Control, Mississippi River and Tributaries St. Johns Bayou and New Madrid Floodway, MO First Phase: Supplemental Environmental Impact Statement* was prepared in 2000. The SEIS supplemented the existing Record of Decision (5 January 1983) for the St. Johns Bayou and New Madrid Floodway Project, as well as the 1976 EIS, titled *Mississippi Rivers and Tributaries, Mississippi River Levees (MRL) and Channel Improvement* that analyzed the overall MRL portion of the MR&T project, including the closure of the New Madrid Floodway.

The Avoid and Minimize Alternative was selected as the preferred plan. The features of this plan included reducing the width of channel work on St. Johns Bayou from 200 feet (with two-sided excavation) to 120 feet (with one-sided excavation); changing work to the right descending bank along a portion of St. James Ditch to avoid higher quality woodlands; and eliminating work proposed on the upper 3.7 miles of St. James Ditch to avoid the State endangered golden topminnow. In addition, nine transverse dikes would be placed in the lower four miles of St. Johns Bayou, and conservation easements would be placed along all improved channels and allowed to revegetate as bottomland hardwoods. Gate operations were modified to facilitate fish passage between the River and the two basins. Mussels would be relocated prior to construction, and a nine-foot wide strip of mussel habitat along one side of the Setback Levee would be avoided. A 10-year mussel monitoring plan would also be developed. Water levels in the lower project area would be managed, providing up to 6,400 acres of flooded land for winter and early spring waterfowl. To compensate for project impacts, 9,557 acres of seasonally inundated agricultural land would be restored to bottomland hardwoods. Additionally, flood easements would be purchased on 765 acres of herbaceous land to benefit shorebirds and fish.

Concerns were expressed by resource agencies and some environmental advocacy groups that environmental losses were not acceptable. A series of meetings were conducted among USACE, the Environmental Protection Agency (EPA), United States Fish and Wildlife Service (USFWS), Assistant Secretary of the Army (Civil Works), the White House Empowerment Board, Missouri Department of Natural Resources (MDNR), Missouri Department of Conservation (MDC), and the Council on Environmental Quality (CEQ) to discuss the project and the environmental concerns. A determination was made that the SEIS should be revised to analyze additional levee closure options, prioritize mitigation sites, and clarify **wetland** impacts.

2002 Revised Supplemental Environmental Impact Statement

The 2002 Revised Supplemental Environmental Impact Statement (RSEIS) was prepared to document the formulation and evaluation of additional alternatives to address the concerns expressed during the completion of the 2000 SEIS. Alternative levee closure locations were evaluated and an array of pump and gate operations that increased the period of connectivity of the floodway to the Mississippi River were considered. The RSEIS also contained a proposal for significant avoid and minimize measures designed to benefit the aquatic and wildlife resources of the New Madrid Floodway.

The selected plan consisted of a 1,000 cfs pumping station and 27.6 miles of channel modifications for the St. Johns Bayou Basin and a closure levee with a 1,500 cfs pumping station for the New Madrid Floodway. A major avoid and minimize measure would allow Mississippi River **backwater flooding** during the spring fisheries season to an elevation of 282.5-feet and 284.4-feet in the St. Johns Bayou Basin and the New Madrid Floodway, respectively.

Avoid and minimize measures that were formulated in the 2000 SEIS, including avoiding golden topminnow habitat, one-sided channel work, transverse dikes, and mussel relocation/monitoring were incorporated into the design. Compensatory mitigation included the acquisition in fee or in easement of a total of 9,140 acres of land. A total of 8,375 acres of land would be reforested and an additional easement purchased on 765 acres of herbaceous lands that could be managed for shorebirds. Mitigation lands would be obtained from willing sellers. Acquisition of frequently flooded lands would be the priority for mitigation in addition to the 1,800 acres of lands surrounding Big Oak Tree State Park and lands adjacent to Ten Mile Pond Conservation Area. The 2002 RSEIS also incorporated hydrologic restoration to Big Oak Tree State Park, 64 miles of vegetated buffer strips along New Madrid Floodway channels, and a wildlife corridor that would connect Big Oak Tree State Park to the Ten Mile Pond Conservation Area. The Record of Decision was signed on 25 August 2003.

The first three tracts of mitigation lands totaling 1,657 acres were purchased and a construction contract was awarded to begin work on Item 2 (New Madrid Floodway closure and pumping station). Legal challenges were filed in the State of Missouri concerning MDNR's issuance of 401 Water Quality Certification for the project and later in the U.S. District Court for the District of Columbia challenging compliance with Federal laws and statutes. During legal proceedings, concerns were raised regarding the project and adequacy of mitigation. As a result, the Record of Decision was withdrawn, construction suspended, mitigation acquisition ceased, and a decision was made to revise the NEPA documentation.

2006 Revised Supplemental Environmental Impact Statement 2

A RSEIS 2 was completed in 2006 that addressed the concerns raised during legal proceedings. The RSEIS 2 did not make any changes to the flood damage reduction features or avoid and minimize alternatives. However, compensatory mitigation was revised. It included a basic mitigation feature that consisted of restoring hydrology to

Big Oak Tree State Park, reforesting a minimum of 1,800 acres of cropland surrounding Big Oak Tree State Park, reforesting 1,293 acres in the St. Johns Bayou Basin, reforesting an additional 2,326 acres of cropland in the New Madrid Floodway, constructing modified **moist soil units** on 765 acres of cropland, providing vegetated buffer strips on 64 miles of New Madrid Floodway channels, establishing a wildlife corridor between Big Oak Tree State Park and Ten Mile Pond Conservation Area, and constructing 387 acres of modified borrow pits to benefit floodplain fish. Additional mitigation techniques that supplement the basic mitigation features were analyzed including additional reforestation, methods to increase duration of flooding on mitigated tracts, restoration/creation of permanent waterbodies, and creation of a spawning and rearing pool by modifying the gravity outlet structure operation. In addition, the RSEIS 2 recommended an adaptive strategy with a goal that mitigation would be achieved when impacted habitat units were replaced, not when a certain quantity of acreage was purchased.

Water quality certification was updated from the State of Missouri, the Record of Decision was signed on 23 May 2006, and construction resumed. A project monitoring plan and the first site specific mitigation plan was coordinated with the interagency team (made up of representatives from EPA, USFWS, MDNR and MDC) and approved by MDNR in compliance with the water quality certification.

2007 Court Decision

On 13 September 2007 the United States District Court for the District of Columbia rendered its decision in Entl. Def. v. United States Army Corps of Eng'rs, 515 F.Supp. 2d 69 (2007). In that decision, the Court overturned the 2002 and 2006 Environmental Impact Statements and the 2006 Record of Decision. In so doing, the Court found that USACE's fish impact analysis and mitigation measures were arbitrarily and capriciously in violation of the Administrative Procedures Act. More specifically, the Court found that the Corps should have included impacts to fish access as a factor in its predictive model; should not have calculated the mitigation value of the **sump area** for fish habitat by classifying it as a permanent water body; should have included impacts to beyond the two-year floodplain; erroneously calculated the value of borrow pits as mitigation; and could not support its assertion that borrow pits were only used to mitigate for permanent water bodies.

2011 Birds Point-New Madrid Floodway Operation

The Birds Point-New Madrid Floodway was operated on 2 May 2011 as a result of record flooding at the confluence of the Ohio and Mississippi Rivers. The Inflow Crevasse (upper crevasse adjacent to Cairo, Illinois) was artificially breached with explosive charges at approximately 10:00 p.m. on 2 May 2011, at which time the river gage at Cairo was at 61.72 feet. The Inflow/Outflow Crevasse No. 2 (lower crevasse in the vicinity of New Madrid) was artificially breached with explosive charges on 3 May 2011, followed by the Inflow/Outflow Crevasse No. 1 (middle crevasse, adjacent to Hickman, Kentucky in the vicinity of Big Oak Tree State Park) on 5 May 2011.

Repairs to the BPNM Floodway are being conducted using a two-phased approach, including: 1) a reset effort, or initial interim measures designed to provide a basic level of protection and functionality before the next flood season; and 2) a restore effort, to provide for the development and installation of permanent measures designed to return the structure to the full level of protection and functionality.

The reset effort has been completed and included filling in of the scour holes that formed as a result of Floodway operation and rebuilding most sections of the crevassed levees on the pre-existing alignment to an interim level of protection. Future restoration efforts would be scheduled based on funding and priority related to other Mississippi River and Tributaries components damaged by the flood. Ultimately, the goal is to provide the same level of protection that existed prior to Floodway operation as authorized by Congress. Analyses in this document assume the same level of flood protection that existed prior to operation.

A summary of the Birds Point-New Madrid Floodway Operation can be found in Appendix L.

Appendix D

Part 2

Historic Conditions



**U.S. Army Corps of Engineers
Memphis District**

**AN ASSESSMENT OF HISTORIC LAND COVER
FOR THE
ST. JOHN'S BAYOU BASIN
NEW MADRID FLOODWAY
REGION**

Prepared For:

**U. S. ARMY CORPS OF ENGINEERS
MEMPHIS DISTRICT
MEMPHIS, TN**

Report 10-05

Mickey E. Heitmeyer

July 2010

AN ASSESSMENT OF
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FOR THE
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REGION

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
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Greenbrier Wetland Services Report 10-05

JULY 2010



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USACE



EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers proposed St. John's Bayou Basin and New Madrid Floodway Project, located in portions of Scott, New Madrid, and Mississippi counties in southeastern Missouri (SJNM) seeks to protect agricultural lands from frequent backwater flooding from the Mississippi River and reduce headwater flooding in the St. John's Bayou Basin in the vicinity of East Prairie. The SJNM project is being designed to include features that will promote landscape-level natural resource conservation and management strategies. This project objective requires an understanding of historic and current landscape conditions in the SJNM. This report provides hydrogeomorphic evaluation to:

1. Determine the historic condition and ecological processes of the SJNM region using a variety of historical and current information including geomorphology, soils, topography, hydrology, faunal and floral accounts, maps and other information sets.
2. Identify changes to physical, biotic, and ecological process components of the SJNM region from the historic condition.

A hydrogeomorphic matrix of understanding of which plant communities historically occurred in different geomorphic, soil, topographic, and hydrological settings was developed to map potential historic vegetation communities in the SJNM. This matrix was developed using comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships to hydrogeomorphic landscape attributes. This matrix



essentially identifies community type and distribution, juxtaposition, and driving ecological processes that created and sustained them. Contemporary geospatial information described the current soil, hydrology, vegetation community structure and function, and resource availability to key animal species. Comparing current landscape condition with predicted historical community type and distribution identified how much the SJNM landscape has changed and which community types have been most altered or destroyed. This information is useful to understand the resiliency of specific communities to environmental changes, the potential impacts of the SJNM project, and potential opportunities to reverse or mitigate/minimize degradations and to restore communities if that is desired.

Major natural communities/habitat types that historically were present in the SJNM included: 1) the main channel and islands of the Mississippi River and its major tributaries; 2) river chutes and side channels; 3) bottomland lakes, often referred to as oxbows; 4) riverfront forest that was dominated by early succession tree species such as willow, silver maple, cottonwood, and sycamore, 5) bottomland hardwood forest (BLH) that contained diverse hardwood tree species including green ash, American elm, box elder, sugarberry, and several oak species; 6) terrace hardwood forest dominated by relatively water intolerant hardwood trees such as post oak and cherrybark oak; 7) slope forest on alluvial fans with mixed upland and floodplain tree species; 8) sand prairie; and 9) sand savanna.

Soil type, geomorphic surface, and hydrology were highly correlated with, and predictive of, the historic community distribution and area in the SJNM. Forest covered over 93% of the Presettlement SJNM. Riverfront forest historically covered 9.3% of the SJNM and was distributed primarily in a band parallel to the active Mississippi River channel on fine sandy loam soils. Most of the current batture of the Mississippi River was historically, and currently is, riverfront forest. Low BLH including bottomland lakes covered about 115,000 acres of the SJNM and was present



mostly in the Holocene meander belt of the Mississippi River and had Sharkey and Alligator clay soils. Intermediate BLH was widely distributed over 23.8% of the SJNM in the Holocene meander belt and some valley train relict channels where flooding occurrence was 1-2 year frequency in the growing season and soils were silty-clay-loam Mollisols and Inceptisols. High BLH was present on about 65,000 acres of the SJNM in several floodplain geomorphic surfaces where growing season flood frequency was 2-5 year occurrence and soils were silt loams. Terrace hardwood covered about 109,000 acres of higher elevation terrace and valley train surfaces with > 50 year flood occurrence and sandy-loam Entisol soils. Slope forest was limited to a few small alluvial fan sites adjacent to the Commerce Hills. Prairie and savanna historically were distributed on the highest elevations of the SJNM where fine loamy sand soils were present on braided stream terraces and the Sikeston Ridge. These two communities may have comprised nearly 33,000 acres in the Presettlement period.

Many changes have occurred in the SJNM landscape from the 1700s to the present. Current land cover in the SJNM is dominated by agricultural cropland, except in the batture areas. Essentially all historic prairie and savanna are gone and total forest area is only 6% and 7.8% of total area in the St. John's Bayou Basin and New Madrid Floodway, respectively. Comparisons of historic forest communities with contemporary aerial photographs that show remnant forest tracts identified that remaining tracts are primarily riverfront forest communities with small tracts of BLH scattered in the region. The only large forest tracts remaining in the SJNM are scattered riverfront forest communities in batture lands and BLH forests at Donaldson Point, Big Oak Tree, and Bogle Woods that is adjacent to the Ten Mile Pond Conservation Area. All of these BLH tracts currently are in public ownership.

The development of potential Presettlement vegetation community maps in this study provides the foundation for understanding the SJNM ecosystem, both past and



present. These maps provide a basis for determining which communities belong in specific geomorphic, soil, and hydrological settings and how contemporary alterations may, or may not, allow these communities to be restored in historic locations if that is desired. The hydrogeomorphic analyses also identified the fundamental driving ecological processes that must be present if restoration of specific communities is attempted.





INTRODUCTION

The U.S. Army Corps of Engineers (USACE) proposed St. John's Bayou Basin and New Madrid Floodway Project (USACE 2009a,b) includes lands in the St. John's Bayou Basin, New Madrid Floodway, and Mississippi River Batture lands in portions of Scott, New Madrid, and Mississippi counties of southeastern Missouri (hereafter SJNM, Fig. 1). The project seeks to protect over 500,000 acres of mostly agricultural land in the region from frequent backwater flooding from the Mississippi River and to reduce headwater flooding in the St. John's Bayou Basin in the vicinity of East Prairie, Missouri. The project also seeks to manage water to enhance natural resource conservation and recreation opportunities using infrastructure that would be constructed for the project through various water management techniques/strategies (USACE 2009b). The project is based on the Flood Control Act of 1954, which authorized closure of a ca. 1,500-foot gap in the Mississippi River Frontline Levee at the southern end of the New Madrid Floodway and the Water Resources Development Act of 1986, which authorized improvements to drainage channels in the St. John's Bayou Basin including the construction of the St. John's Bayou and New Madrid pump stations.

The SJNM region was formed by numerous fluvial dynamics associated with large volumes of outwash and melt water from continental glaciers and subsequent drainage from the historic and current Mississippi and Ohio rivers (Saucier 1994). The contem-

porary SJNM landscape reflects various sequential periods of extensive scouring, sediment deposition, and migration of drainage channels especially in the Pleistocene period. During the pre-European settlement period of the mid to late 1700s (hereafter Presettlement period) the region supported extensive forest communities with some sand-type Prairie

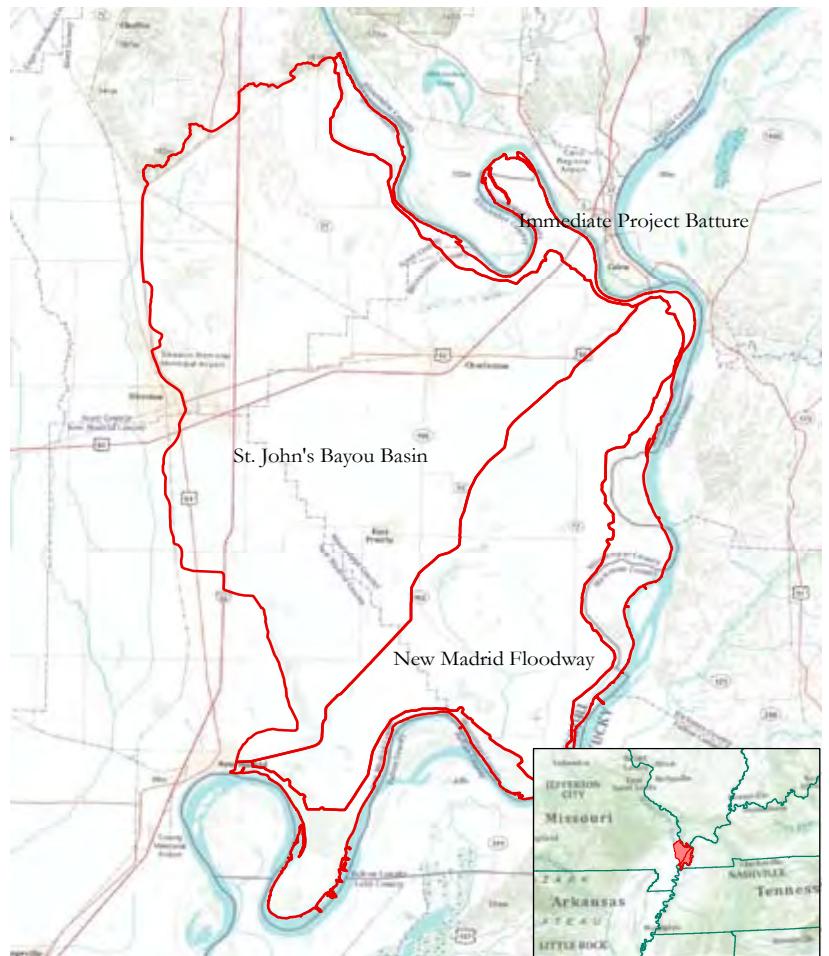


Figure 1. Location of the SJNM and major hydrogeomorphic regions and areas.

and Savanna on higher ridges (GLO 1817-1840, Nuttall 1821 and others). These plant communities provided many economic and highly abundant and diverse resources that supported diverse animal communities. The primary ecosystem processes or “drivers” that sustained this ecosystem were seasonal backwater flooding from the Mississippi River and its local tributaries, regular deposition of nutrients to rich alluvial soils, occasional scouring and reworking of floodplain sediments, and vegetation disturbance from fire, wind, and herbivory (e.g., Heitmeyer et al. 2005). In the last 100 years, the Presettlement landscape of the SJNM has been greatly altered by changes in topography, hydrology, and conversion of most native habitat areas to extensive agricultural production (e.g. Korte and Fredrickson 1977).

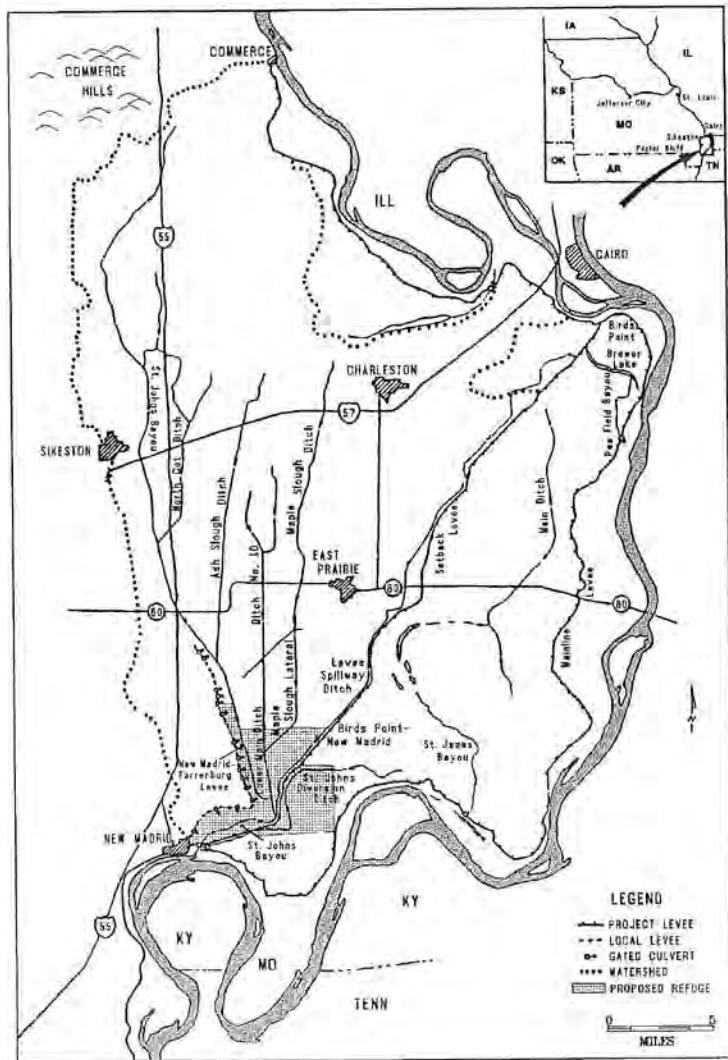


Figure 2. Location of major flood control and drainage ditches and levees in the SJNM (modified from USFWS 1993).

Currently, large areas in the SJNM flood annually as the Mississippi River rises and causes backwater flooding into the region (USACE 2009a). Efforts to reduce annual flooding of agricultural lands and occasional flooding of towns including East Prairie, Charleston, New Madrid, and Pinhook began coincident with extensive agriculture and settlement of the region in the late 1800s and early 1900s (Douglass 1912) and intensified following large floods in 1927 and 1937 (USACE 2009a). In the 1920s and 1930s a levee was built from New Madrid to the southern part of Sikeston Ridge (usually referred to as the New Madrid-Sikeston or New Madrid-Farrenburg Levee), a large mainstem/frontline levee was constructed along the Mississippi River from Commerce to New Madrid, and a setback levee was built from Birds Point to New Madrid (usually called the Birds Point-New Madrid Levee) to establish the

New Madrid Floodway (Fig. 2). This levee construction separated the SJNM into three distinct hydrological regions: 1) Batture along the Mississippi River, 2) New Madrid Floodway, and 3) St. John's Bayou Basin. Initially, a 4,200 foot gap was left in the southern end of the St. John's Bayou levee. Later this gap was closed with a levee extension, and floodgates were installed at the gap closure site in 1953 (USACE 2009a). The floodgates are left open to allow for interior drainage except during periods of high Mississippi River stages. During flood events, the floodgates are closed to prevent Mississippi River backwater flooding. Although closing the floodgates prevents this backwater flooding, it also blocks interior drainage and causes flooding behind the levee and floodgates. This headwater accumulation from the St. John's Bayou watershed can inundate about 10,056 acres, of which 6,312 acres are croplands. The south end of the New Madrid Floodway also left a 1,500 foot gap that did not join the frontline Mississippi and setback Birds Point-New Madrid levees. Although the gap in the levee provides drainage to the New Madrid Floodway, it also allows backwater flooding from the Mississippi River to enter the SJNM. Since 1960, large backwater floods from the Mississippi River into the SJNM have occurred in 1961, 1962, 1964, 1972, 1974, 1975, 1979, 1983, 1984, 1993, 1994, 1995, 1996, 1997, 1998, 2002, and 2008 (USACE 2009a). During 1996-98 floodwaters inundated large areas in the SJNM through late June each year and caused major losses of agricultural

production. Based on previous analyses conducted by the USACE, a 2-year recurrence Mississippi River flood in the New Madrid Floodway inundates approximately 17,316 acres, of which 11,843 are agricultural croplands (USACE 2009a). In 2002, combined Mississippi River and local stream flooding covered about 77,000 acres, of which 61,400 were croplands, in the SJNM. Lost agricultural production obviously impacts local economies. Altered hydrology also has compromised management and restoration of certain remnant BLH sites including Big Oak Tree State Park (Flader 1993, USACE 2009a).

The SJNM Project is being designed to include features that will promote landscape-level natural resource conservation and management strategies along with providing season flood control protection. Incorporation of natural resource conservation features and objectives in the SJNM Project requires an understanding of historic and current landscape conditions including the basic physical and biotic structure, ecological processes, and landscape-scale interactions that control ecosystem characteristics, functions and values. Hydrogeomorphic methodology (see Heitmeyer 2007) now is commonly used to evaluate ecosystem restoration and management options in large river floodplain ecosystems in North America (e.g., Heitmeyer 2008, Heitmeyer et al. 2002, Heitmeyer and Fredrickson 2005, Heitmeyer and Westphall 2007, Heitmeyer et al. 2009). This Hydrogeomorphic methodology obtains and analyzes historic and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrological regimes, 5) plant and animal communities, and 6) physical anthropogenic features of landscapes ranging in scale from site-specific tracts to large watersheds. The Hydrogeomorphic perspective is valuable for the SJNM to determine the historic landscape context and configuration of the region and the subsequent changes to this system that have led to the contemporary condition. This report provides data and analyses to meet two basic objectives:

1. Determine the historic condition and ecological processes of the SJNM region using a variety of historical and current information including geomorphology, soils, topography, hydrology, faunal and floral accounts, maps, and other information sets.
2. Identify changes to physical, biotic, and ecological process components of the SJNM region from the historic condition.

METHODS

The first objective of this report identifies and predicts landscape context and potential community type and distribution for the SJNM by developing a Hydrogeomorphic “matrix” of understanding of which plant communities historically occurred in different geomorphic, soil, topographic, and hydrological settings (see e.g., Heitmeyer et al. 2002, Heitmeyer 2008, Klimas et al. 2009). The “baseline” for the “historic” condition in the SJNM used in this report is the time immediately prior to major European settlement in the area in the mid to late 1700s. While some settlers occupied the SJNM prior to the late 1700s, little alteration to native vegetation communities, regional hydrology, or topography had occurred by then (see e.g., Douglass 1912, Ogilvie 1967 and other references in a later section in this report).

The Hydrogeomorphic matrix of understanding, and prediction of, potential historic vegetation communities is developed from comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances (e.g., Nelson 2005). These plant-abiotic correlations are in effect the basis of plant biogeography and physiography whereby information is sought on where plant species, and community assemblages, occur throughout the world relative to geology and geomorphic setting, soils, topographic and aspect position, and hydrology (e.g., Barbour and Billings 1991). The Hydrogeomorphic matrix allows maps of potential historic vegetation communities in the SJNM to be produced in an objective manner based on the botanical correlations that identify community type and distribution, juxtaposition, and “driving” ecological processes that created and sustained them. Obviously, the predictions of type and historic distribution of communities can only be as good as the understanding and documentation of plant-abiotic relationships and the geo-spatial data for the abiotic variables for a location and period of interest, such as Presettlement period.

In the Upper Mississippi Valley ecoregion that includes the SJNM, the major vegetation communities that were present during the Presettlement period are known (Nigh and Schroeder 2002, Nelson 2005) and the botanical relationships of these communities with abiotic factors are extensively documented and

robust (e.g., see reviews in Wharton et al. 1982, Conner and Sharitz 2005, Klimas et al. 2009). For example, the relationships of BLH species to seasonal and annual flooding regimes and local topography in the Upper Mississippi Alluvial Valley (MAV) have been widely studied (e.g., Hall and Smith 1955, Broadfoot and Williston 1973, Bedinger et al. 1979, Fredrickson 1979, Keeley 1979, Black 1984, Hook 1984, Heitmeyer et al. 1989, 1991, and many others). As a specific example, the distribution of pin oak (*Quercus palustris*) and willow oak (*Quercus phellos*) is centered in sites with silt-clay-loam soils, dormant season flooding for up to 3 months, and within the 2-5 year flood frequency zone (Heitmeyer et al. 1989, 2006, Fredrickson and Batema 1992, Klimas et al 2009). The interrelationships among abiotic factors for the Upper MAV also are well understood and documented. For example, the type and spatial position of soils generally are closely related to geomorphic surface and formation. As a specific example, Crevasse sandy soils are found on the inbank sides of natural levee crests (Autin et al. 1991: 572). Excellent detailed maps of the geomorphology (Saucier 1994), soils (U.S. Department of Agriculture, SSURGO databases), and topography (LIDAR surveys conducted by the USACE) of the SJNM are available. In contrast, historic hydrology information for the SJNM is less available. Long-term river gauge data dating to the late 1800s and early 1900s are available for the Mississippi River at New Madrid and Thebes, respectively and to the early 1900s for the Ohio River at Cairo. Unfortunately, the stage-discharge relationships and the recurrence intervals of various river levels that caused backwater and headwater flooding into the SJNM prior to construction of the initial mainstem levees in the region are not known.

The robust vegetation community relationships in the Upper MAV enable a well-validated understanding of where historic major plant communities in the SJNM are located relative to geomorphic setting, soils, and hydrological regime. Consequently, even though Presettlement hydrology data area not available for the region, the confirmed relationships of species to other abiotic variables provide strong inference as to what the historic hydrological regime was for various locations. The primary communities in the SJNM are BLH and Sand Prairie/Savanna. These communities have relatively long generation cycles and their occurrence at sites indicates long-term response and adaptation to repetitive inter-annual and seasonal patterns of hydrology. If confidence is reached in understanding the position of a historic community type based on historic maps and botanical correlation

with other abiotic variables including specific geomorphology, soils, and topography, then by default, the historic hydrological regime for a site also can be safely predicted. For example, if a historic site supported High BLH, then by default the site had (long-term average) short duration dormant season flooding within a 5-year flood frequency zone.

The sequence of methodology used to prepare the Hydrogeomorphic matrix and map of potential historic communities for the SJNM was:

1. The general distribution of major vegetation community/habitat types including Forest, Prairie, Bottomland Lake, river channels and chutes, etc. (Nigh and Schroeder 2002, Nelson 2005, Heitmeyer 2008) was determined from GLO surveys (General Land Office 1817-1840), historic cartography (e.g., Hutchins 1784, Collot 1826, De Finiels maps from the 1800s in Ekberg and Foley 1989, Colton 1857, Couzens 1861, Warren 1869 Mississippi River Commission 1881, 1893-1904, Brauer et al. 2005, Heitmeyer et al. 2006), and early settlement/naturalist accounts (e.g., Brackenridge 1814, Nuttall 1821, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Beckwith 1887, Douglass 1912). A generalized map of the historic distribution of communities using the above collective information was then overlain on contemporary geomorphology (Saucier 1994), soils (U.S. Department of Agriculture (USDA) SSURGO soils data), flood frequency (data from USACE, Memphis District), and LIDAR topography maps (from USACE, Memphis District).
2. The general correspondence of Presettlement vegetation communities from the above map sources with contemporary abiotic geomorphology, soils, and topography layers was determined where possible. Confidence in this “map” correspondence was best when geo-referenced digital maps were available, such as the GLO surveys, and was weakest when older maps and cartography are used. Despite the imprecision of some older maps and accounts, analyzing habitat information from these sources provides useful information to determine the general distribution of communities. Using this first-step overlay of map information, relationships between communities and abiotic factors sometimes became clearly defined by one or two factors. For example, in the SJNM all chute-and-bar surfaces (Woerner et al. 2003) with recently deposited and scoured sandy

- soils (USDA SSURGO data) along the current Mississippi River channel were historically Riverfront Forest. Often, however, it was necessary to use multiple abiotic variables to understand botanical relationships.
3. Remnant native vegetation communities in the SJNM were identified from aerial photographs and other sources (e.g., Missouri Natural Areas Committee 1996). Select sites were visited in 2009 and 2010 to document vegetation characteristics, such as species composition, and to determine if the sites matched the community types predicted from step #2. If the historic maps and contemporary field data were consistent, then the field sites were considered a reference site of former community types (e.g., Nelson 2005, Nestler et al. 2010).
 4. Major forest community types were subdivided into ecologically distinct sub-communities using botanical information for the respective communities where possible. For example, BLH communities in southeast Missouri and northeast Arkansas typically are distributed along topographic/hydrologic gradients and can be separated using the combination of soils, geomorphology, and topography (e.g., Nelson 2005, Heitmeyer et al. 2006, Klimas et al. 2009). BLH Forests in the SJNM occupied divergent geomorphic, soils, topographic, and hydrological settings ranging from natural levees, point bar ridges and swales, relict valley train channels, and Holocene depressions and isolated abandoned channels. For example Hpm1 Point Bar areas in the inside bends of abandoned Mississippi River channels contained meander scrolls with alternating parallel bands of lower elevation swales and higher elevation ridges. Swales in these sites typically had silt-clay soils with 1-2 year flood frequencies whereas ridges contained sandy- or silt-loams soils with 2-5 year flood frequencies. Consequently, by mapping soils and topography on point bar surfaces, BLH forest areas could be sub-divided into swale-type Intermediate BLH communities that have more water tolerant species such as overcup oak (*Quercus lyrata*), red maple (*Acer rubrum drummondii*), sugarberry (*Celtis laevigata*), and green ash (*Fraxinus pennsylvanica*) vs. the ridge-type High BLH communities that were dominated by American elm (*Ulmus americana*), winged elm (*Ulmus alata*), box elder (*Acer negundo*), pin and willow oak, and pecan/water hickory (*Carya aquatica*).
 5. A matrix of predicted community types in relationship to the geomorphology, soils, topography, and flood frequency variables discovered in steps 1-4 above was prepared.
 6. The position of predicted communities from the Hydrogeomorphic matrix on the composite digital geo-referenced maps of geomorphology, soils, topography, and flood frequency was mapped,
 7. Aerial photographs were used to identify remnant habitats of the map predicted types (i.e. Sand Prairie, BLH and Riverfront Forest communities, Bottomland Lake, etc.) and reference sites and remnant habitats were revisited to determine the vegetation that was present. This field data collection was similar to step #3 in finding reference sites that represented and verified various communities.
 8. Based on field and map data developed in steps 6 and 7, the matrix was refined and areas or communities were identified where correspondence with various abiotic factors were weaker. For example, geomorphic surface, soil and topography data predicted a greater extent of Sand Prairie and/or Sand Savanna on Sikeston Ridge and Pvl1 surfaces (Fig. 3) than was shown on the GLO maps. Some older accounts and maps from this area also suggest a greater extent of Prairie or more Open Woodland that likely was Savanna on these geomorphic surfaces in the late 1700s compared to GLO maps made from 1817-1840 (Hutchins 1784, see also Schroeder 1981). In this specific case it was necessary to overlay historic maps from the Pvl1 surface onto current digital maps to produce an estimate of the Presettlement Prairie and Savanna communities and how their distribution was related to current landscape features.
 9. A map of potential historic vegetation communities was prepared by sorting the SJNM landscape relative to the Hydrogeomorphic matrix parameters. For example, Riverfront Forest was plotted where the unique matrix combination of geomorphic surface, soil types, topography, and known or assumed hydrological regime occurred.

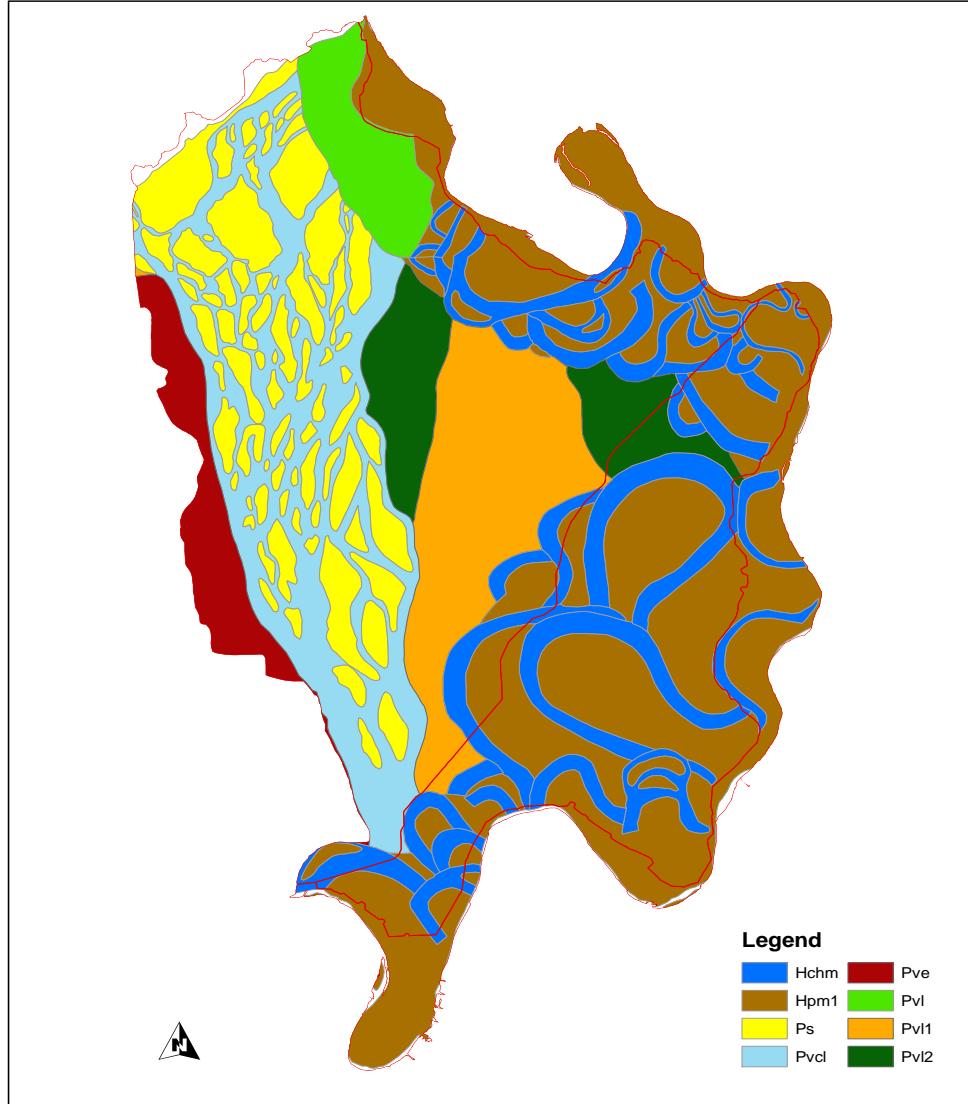


Figure 3. Geomorphic surfaces in the SJNM (from Saucier 1994). Hchm – abandoned channels of the Mississippi River, Hpm1 – point bar (meander scroll) deposits of Mississippi River meander belt 1 (newest age), Ps – sand dune fields and eolian deposits on valley trains, Pvcl – relict channels of Late Wisconsin stage valley trains, Pve – Early Wisconsin stage valley train, Pvl – Late Wisconsin valley trains where levels (ages) are separately delineated, Pv1 – Late Wisconsin stage valley train level 1 (newest age) includes interfluves and relict channels unless channels are separately delineated, Pv12 - Late Wisconsin stage valley train level 2 (next newest age) includes interfluves and relict channels unless channels are separately delineated.

The second objective used contemporary geo-spatial map information to describe alterations to the historic ecosystem attributes in relation to land form and soils, hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species. A major part of this objective is determining how much of the Hydrogeomorphic-predicted Presettlement vegetation communities have been lost and converted to other land types. Overlaying the matrix potential historic community map (Step #9 above) on 2009 USDA National Agricultural Inventory Program (NAIP) photographs provides this

template and analyses in conjunction with field visits to remnant communities. This evaluation and comparison of historic vs. current land cover provides an objective way to assess current conditions and types and magnitude of changes. This comparison identifies which communities have been most destroyed or degraded and is useful to understand the resiliency of specific communities to environmental changes, the potential impacts of the SJNM project, and potential opportunities to reverse or mitigate/minimize degradations and restore communities if that is desired (e.g., Heitmeyer et al. 2006, Heitmeyer 2008).



THE HISTORIC SJNM ECOSYSTEM

The current geomorphology and surficial architecture of the SJNM are products of fluvial dynamics of sediment and water discharge primarily during the last glacial-interglacial cycle within the MAV (Autin et al. 1991, Saucier 1994). Wind and tectonic action further shaped land forms and surfaces. The SJNM region is underlain by deep basement rock deposited by Cretaceous marine deposits and sediments from surrounding uplands that filled in a continental rift that created the Gulf of Mexico in the Late Triassic and Early Jurassic times (Buffler 1991). Jackson, Wilcox, and Clairbone deposits from the Eocene period overlie the basement Cretaceous rock and occasionally subcrop to the surface of Upper MAV areas (Saucier 1994). The New Madrid Seismic Zone also runs under or near the SJNM and is an ancient rift fault that did not completely develop or separate (Fig. 4). This Seismic zone extends from ca. Cairo, Illinois to near Helena, Arkansas and caused the most severe earth tremors ever recorded in North America in late 1811 and early 1812, with the epicenter near New Madrid (Russ 1982).

The MAV, including the SJNM, was created by cyclic Pleistocene glaciation events. Although continental ice sheets did not extend into the MAV, they caused deranging pre-glacial drainage on several occasions and created southward-trending rivers and floodplain valleys that carried large volumes of glacial meltwater and outwash from the Interior of North America to the Gulf Coast (MaGill 1980, Saucier 1994). The

SJNM includes parts of the St. Francis Basin and the Holocene Mississippi and Ohio River meander belts and includes numerous former channels and courses of both rivers that were braided in a valley train network (Fig. 3, Saucier 1974, Autin et al. 1991). Most of the SJNM is within the Cairo Lowlands (also commonly called the Charleston Lowlands),

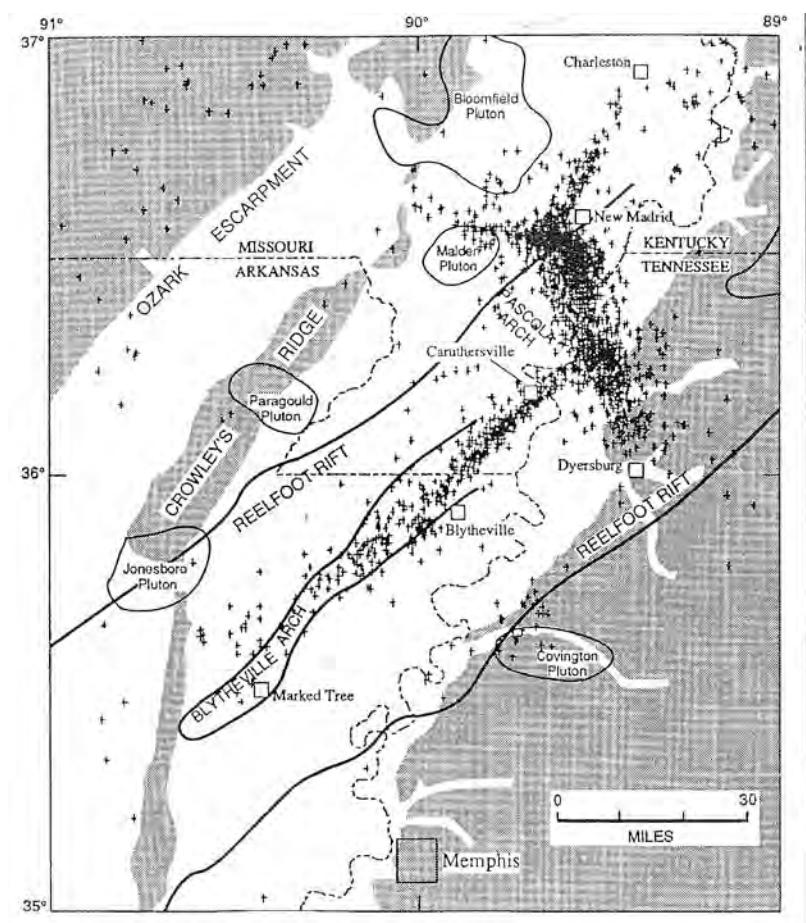


Figure 4. Map of seismic activity and epicenters of earthquakes in the Lake County Uplift zone along the New Madrid fault zone (from Saucier 1994).

which contains elevation alluvial surfaces bounded by Sikeston Ridge to the west, the Mississippi River to the south and east, and the Commerce Hills on the North (Saucier 1990).

Prior to continental glaciations a large percentage of runoff from northern parts of North America drained northward through the Great Lakes region (Frye et al. 1965, Simons et al. 1974). Most pre-glacial rivers that drained south into the Mississippi Embayment (the present MAV) were small and drained from relatively small watersheds. When glacial ice sheets formed and blocked northern drainage routes, glacial melt waters were forced south and carried large volumes of water, silt, sand, and gravel. These waters and suspended materials subsequently formed various channels and floodplains of the Missouri, Mississippi, and Ohio rivers. The historic Mississippi River flowed south along the southern edge of the Ozark Escarpment and changed course many times following glacial melt periods (Saucier 1974). Current landscapes along the Mississippi River mostly reflect river movements post-Wisconsin glaciation during the last 18,000 years (Saucier 1968, 1994). During this period the Mississippi River initially flowed southwest along the Ozark Escarpment and followed a path south along the current Black and White River floodplains to a point near Helena, Arkansas where it joined the Ohio River. Concurrently, the Ohio River flowed southwest in a braided course through the Cache Lowland of southern Illinois into the alluvial valley where it turned south and stayed east of Sikeston Ridge and occupied the current Mississippi River floodplain, including the SJNM region, to Helena (Gough 2005). Sikeston Ridge represents a 30-mile long remnant valley train terrace deposited in the mid-Wisconsin period about 40,000 to 60,000 years BP by the Ohio River as it discharged from the Cache Lowland into the St. Francis Basin (Saucier 1994). Sikeston Ridge is surrounded by Late Wisconsin Mississippi River glacial outwash as depocenters shifted east and the active outwash plain surface degraded to a lower elevation.

Both the Mississippi and Ohio rivers were small and somewhat restricted in early Wisconsin times, but expanded as the Wisconsin ice sheet began to melt and became large rivers during summer when melt waters peaked. From late fall to spring, before melting commenced each year or after it slowed, water levels dropped and the rivers followed many separate braided channels known as Valley Trains (Saucier 1994). This braided characteristic created

a mosaic of channels and adjacent interfluve floodplain terraces often superimposed on older historic alluvial deposits.

When the Laurentide (Wisconsin) ice sheet began to rapidly melt about 18,000 years before the present (BP), a major increase in meltwater and outwash moved south in the Mississippi River floodplain (Saucier 1994). This volume of glacial runoff increased progressively, but in an episodic manner for several thousand years and by 14,000 BP the volume of water in the Mississippi River was over five times the current discharge. Accumulation of sedimentary material in the former Mississippi River floodplain through the Advance Lowlands in southeast Missouri gradually created a dam between Crowley's Ridge and the Ozark Escarpment near Puxico, Missouri and created a glacial lake known as Lake Girardeau in the Advance and Drum Lowland (Saucier 1968). When melt waters reached and filled this glacial lake, water began overflowing and eroding points in Crowley's Ridge and carved a new Mississippi River channel through the Bell City-Oran Gap and southward through the Missouri Bootheel region as early as 16,500 BP. As the volume of water through the Bell City-Oran Gap escalated, the river reworked a large area of Early Wisconsin age outwash and constructed a new Valley Train geomorphic complex (Pvcl, Ps, and Pv12 surfaces shown on Fig. 3) at a slightly lower elevation than had existed previously. Relict Valley Train channels (Pvcl) remain obvious in a north-south band east of Sikeston Ridge and Pv12 surfaces extend to the more recent Holocene Meander Belt. O'Bryan Ridge is a more pronounced slightly higher elevation area south of Wilson City. The Ohio River apparently abandoned the Cache Lowland at this time and adopted its present course past Cairo (Esling et al. 1989). No valley train deposit in the St. Francis Basin during this time can be attributed to the Ohio River, but the braided Ohio River flowed near the base of eastern floodplain bluffs and continued to merge with the Mississippi River near Helena (Saucier 1994).

At about 12,000 BP the Wisconsin glacial period ended and the postglacial period began. At this time a sudden shift in atmospheric circulation patterns initiated a strong trend toward warmer and drier conditions in the Upper MAV. After a relatively brief warming period ice sheets readvanced in the Great Lakes region about 10,500 BP. This ice sheet closed the St. Lawrence Valley outlet for the Upper Mississippi River and caused increased meltwater flow back into the Lower Mississippi River Valley

(Saucier 1994). This increased outwash flow of the Mississippi River was then able to spill through and rapidly widen and deepen a small existing upland drainage feature in the Commerce Hills south of Cape Girardeau, Missouri. This erosion through the Commerce Hills ultimate created the Thebes Gap that subsequently became the main channel of the Mississippi River. A depositional alluvial fan that contained a braided stream terrace configuration (Pvl1, Fig. 3), known as the Charleston Fan, subsequently formed immediately downstream from Thebes Gap where river water slowed and dropped sediments over a ca. 150 square mile area as it exited the constricted gap. This relatively new Charleston Fan extended south to Bayouville and contained the higher elevation Barnes Ridge at its south end.

After the Mississippi River channel cut through Thebes Gap it then occupied the former channel of the Cache River in southern Illinois and subsequently joined the Ohio River at Cairo, Illinois. At this time the Mississippi River also changed from a braided stream system to an actively meandering main channel regime between Cairo and Memphis about 10,000 years BP. Various geomorphic investigations have identified nearly 15 channel changes in the SJNM region in the last 10,000 years, four of which occurred since the mid 1700s (Fig. 5). Each channel change was accompanied by the development of new natural levees along the river channel, reworking of former alluvial and channel belt sediments, and establishment of sediment plugs in former channels that then created abandoned channel "oxbows."

The active Seismic Zone in the SJNM area also has influenced surface and subsurface geology, topography, and hydrology in the region. On the Holocene floodplain and adjacent Valley Train surfaces, the New Madrid earthquakes have caused liquefaction-induced ground failures over nearly 10,000 km² in southeast Missouri and northeast Arkansas (Fig. 6, Saucier 1977, Obermeier 1989). Sand boils, lateral spreads, ground fissures, and localized distortion and warping of ground surfaces are common seismic-caused features. In the SJNM region, earthquake-induced liquefaction occurs in areas where a thin cohesive bed overlies a noncohesive bed, so that susceptibility is greatest where ground water saturates the noncohesive layer

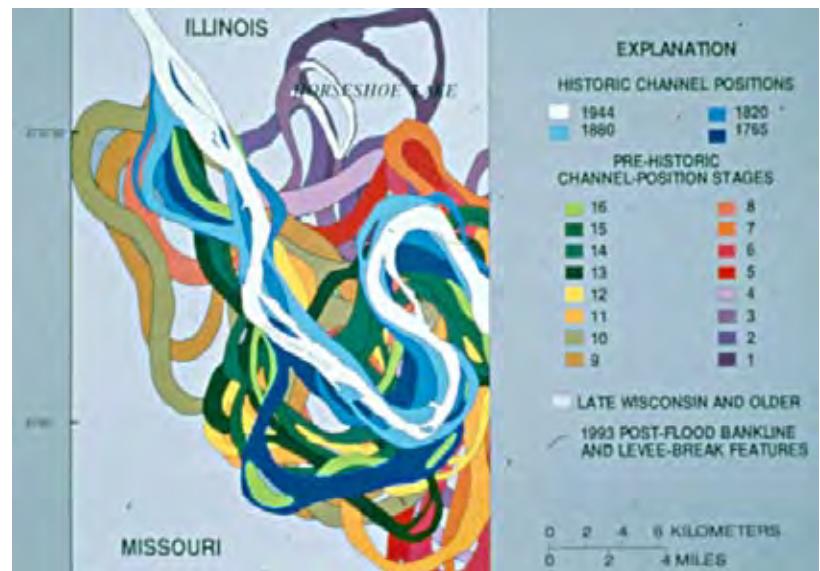


Figure 5. Possible historic sequence of Mississippi River channel migration in the northern part of the SJNM (modified from Fisk 1944).

(Autin et al. 1991). Patterns of ground failure then are controlled by liquefaction, susceptibility, earthquake magnitude, and ground response characteristics.

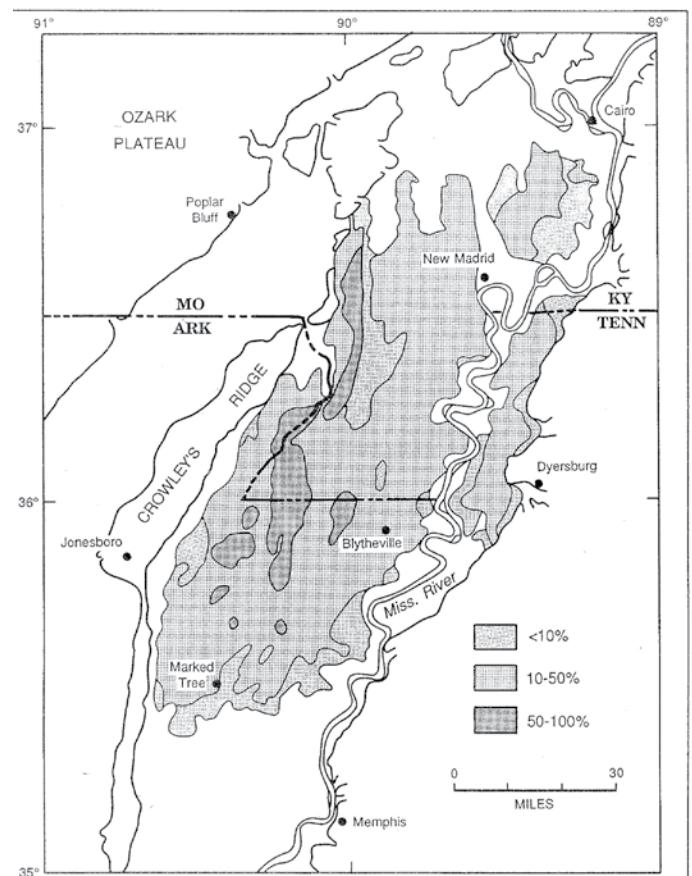


Figure 6. Distribution of seismic liquefaction features in the New Madrid Seismic Zone (from Saucier 1994).

Earthquakes in the region remain highly active since the large 1811-12 event; nearly 500 earthquakes with a magnitude of 3.0 mb or higher occurred from 1812 to 1974 (Saucier 1994:290). Twenty of these earthquakes measured 5.0 to 6.2 mb. Earth movements caused by seismic activity in the Lake County Unit block that includes the SJNM; suggest that low-order streams adjust their gradients to corresponding uplift patterns (Merritts and Hesterberg 1994).

In summary, the extremely active fluvial history of the Upper MAV created the contemporary heterogeneous geomorphologic surface context in the SJNM (Fig. 3). The contemporary land sediment assemblage map for the SJNM includes and identifies: 1) the eastern edge of Sikeston Ridge (Pve) on the far west side of the SJNM that was created 40-60,000 years BP by the Ohio River, 2) relict channels and inter-fluve terrace sand deposits (Pvcl and Ps surfaces) created by an active valley train drainage complex

12- 6,000 years BP and subsequently became partly reworked following the diversion of Mississippi River water through Thebes Gap, 3) late Wisconsin-age braided stream networks where levels are not distinguished (Pvl2), 4) the Charleston alluvial fan (Pvl1) created about 10,000 years BP that was deposited on top of Pvl2 surfaces, 5) the recent (10,000 years BP to the present time) meander belt of the Mississippi River channel and its floodplain including point bars and meander scrolls (Hpm1), and 6) numerous abandoned channels (Hchm) and accompanied relict natural levees.

SOILS

Most of the SJNM is covered by nearly 200 feet of alluvial deposits of gravel, sand, silt, and clay (Luckey 1985, Saucier 1994). Soils in the region

reflect the age and source of alluvial material and include a heterogeneous array of Alfisols, Entisols, Inceptisols, Mollisols, and Vertisols (Fig. 7). The deposition of sand sediments in Valley Train areas was followed by a period when well-developed Alfisols formed on higher “ridge” areas on the Sikeston Ridge and the edge of the current Holocene Mississippi River meander belt (Autin et al. 1991). Minimally developed Entisols are sites of continuous deposition and unweathered colluviums materials on higher terrace elevations in the Valley Train braided stream terrace regions of the SJNM. Entisols cover all of the higher elevation portions of the Charleston Fan (Pvl1) and interfluve areas of western Ps and Pvl2 surfaces. Mollisols contain more developed soil horizons and often include loam-clay veneers of varying depth. These soils developed in relict valley train channels of Pvcl and Pvl1 and 2 surfaces and on higher elevation ridge-and-swale surfaces on point bar meander scrolls. Inceptisols are present on Holocene Mississippi River natural levee areas and typically have more coarse sediments with little clay present. Vertisols occupy large areas of the Holocene

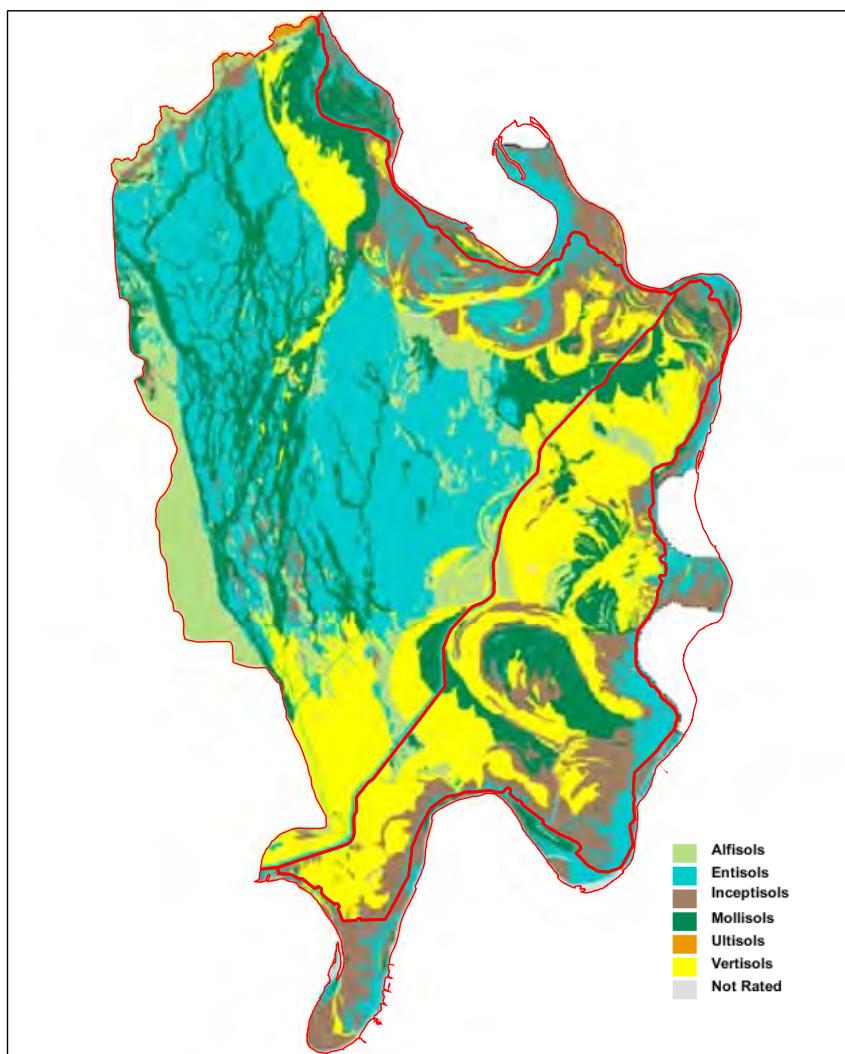


Figure 7. Broad soil taxonomy of the SJNM (modified from Mayhan 2001).

meander belts of the Ohio and Mississippi River and contain expansive clays that occur in the numerous abandoned channels and lower floodplain depression areas of the SJNM. Clay layers in these Vertisols are usually 10-20 feet thick and overlie 120-150 foot thick sands and gravels.

Nearly 60 individual soil types occur in the SJNM (Fig. 8) and reflect their age and affiliation with the fluvial-geomorphic history of individual locations. Sharkey-Alligator thick clay Vertisols dominates most Holocene abandoned channels and floodplain depressions. Sharkey-Alligator clays are heavy expansive sediments deposited in calm water areas including the bottoms of abandoned channels, backwater depressions, and some point bar swales. In contrast, Caruthersville sand loams and Commerce silty clay loams are present in Hpm1 Inceptisols that cover areas with strong water currents near recently scoured edges of river channels and natural levees, respectively. Braided stream terraces and sand dunes (Ps, Pvl) typically are covered with younger, less well developed, Entisols that primarily are Scotco sand, Boskett sandy loam, Clana loamy fine sand, and Lilbourn fine sandy loams. Bosket fine sandy loam also covers most of Sikeston Ridge. Relict valley train channels (Pvcl) contain Mollisols with more clay and loam than the terraces and are usually dominated by Sikeston loam and Diehlstadt sandy clay loam soils. Sand-based Clana soils cover most of the Charleston Fan. Mollisols also cover much of the inside meander scroll ridge surfaces of abandoned channel point bars and include many silt-loam soil types such as Acadia, Dundee, Falaya, Reelfoot and Towosaghy.

TOPOGRAPHY

Land surface elevation in the SJNM ranges from 280 to 325 feet above mean sea level (amsl) (Fig. 9). Topography in the region is complex and reflects the geomorphic surfaces present. The combination of ridge-and-swale point bar surfaces, abandoned channels, and natural levees on the east part of the SJNM create elevation differences of up to 10-20 feet, and dramatically different flood frequencies, within short distances (Fig. 10). For example, natural levees along deeper abandoned channels may be 20 feet higher than the bottom of the channel. Likewise, the intricate valley train network of braided stream terraces created mosaics of relict channels and inter-fluves ridges that vary by over 10 feet locally. The Sikeston Ridge on the far west side of the SJNM is

up to 30-40 feet higher than the surrounding Late Wisconsin Mississippi River glacial outwash valley train configurations (Pvl2). The Charleston Fan Pvl1 surface also is > 10 feet higher than the adjacent Pvl2 valley train complex and the Hpm1.

CLIMATE AND HYDROLOGY

The climate of the SJNM is characterized by warm summers and relatively mild winters. Average monthly temperatures range from the high 20s (degrees Fahrenheit) in January to about 90 degrees in July (Fig. 11). The frost-free growing season ranges from 174 days in 9 of 10 years up to 212 days one of every 10 years (Festervand 1981). During summer the sun shines 80% of the time while it shines about 50% of winter days. Average relative humidity in mid-afternoon is about 60% in summer with occasional 90% humidity levels occurring. Annual precipitation has ranged from 27 to 80 inches during the period of record, with an average of 47.2 inches of rainfall and about 8 inches of sleet and snow. The wettest months typically are March through May while August and October are dry (Fig. 12). Frontal systems associated with low pressure systems provide the majority of local rainfall. During summer, convection clouds caused by high daily temperatures and humidity levels often cause afternoon showers. Thunderstorms occur about 50 days each year (Festervand 1981). The prevailing wind is from the southwest. Long term precipitation data from New Madrid indicate somewhat alternating patterns of high vs. low annual precipitation in the region. For example, dry years with < 40 inches of rainfall occur about every 6-8 years, while wet years with > 60 inches of rain occur about every 8-10- years (Fig. 13). This alternating pattern of annual precipitation is relatively similar to the 6-8 year pattern in the Mingo Basin about 60 miles to the northwest (Heitmeyer et al. 1989).

Annual discharge in the Mississippi River Reach of the SJNM varies seasonally and annually. Mean monthly discharge at Thebes typically exhibits a unimodal pattern of highest flow in April and May followed by a gradual decline to relatively low stable levels from August to January (Fig. 14). This pattern reflects increases in precipitation and snowmelt in the Upper Mississippi River watershed in spring and corresponding decreased precipitation and runoff from summer through winter. While the average seasonal pattern of river discharge is fairly unimodal, the monthly ranges of discharge are

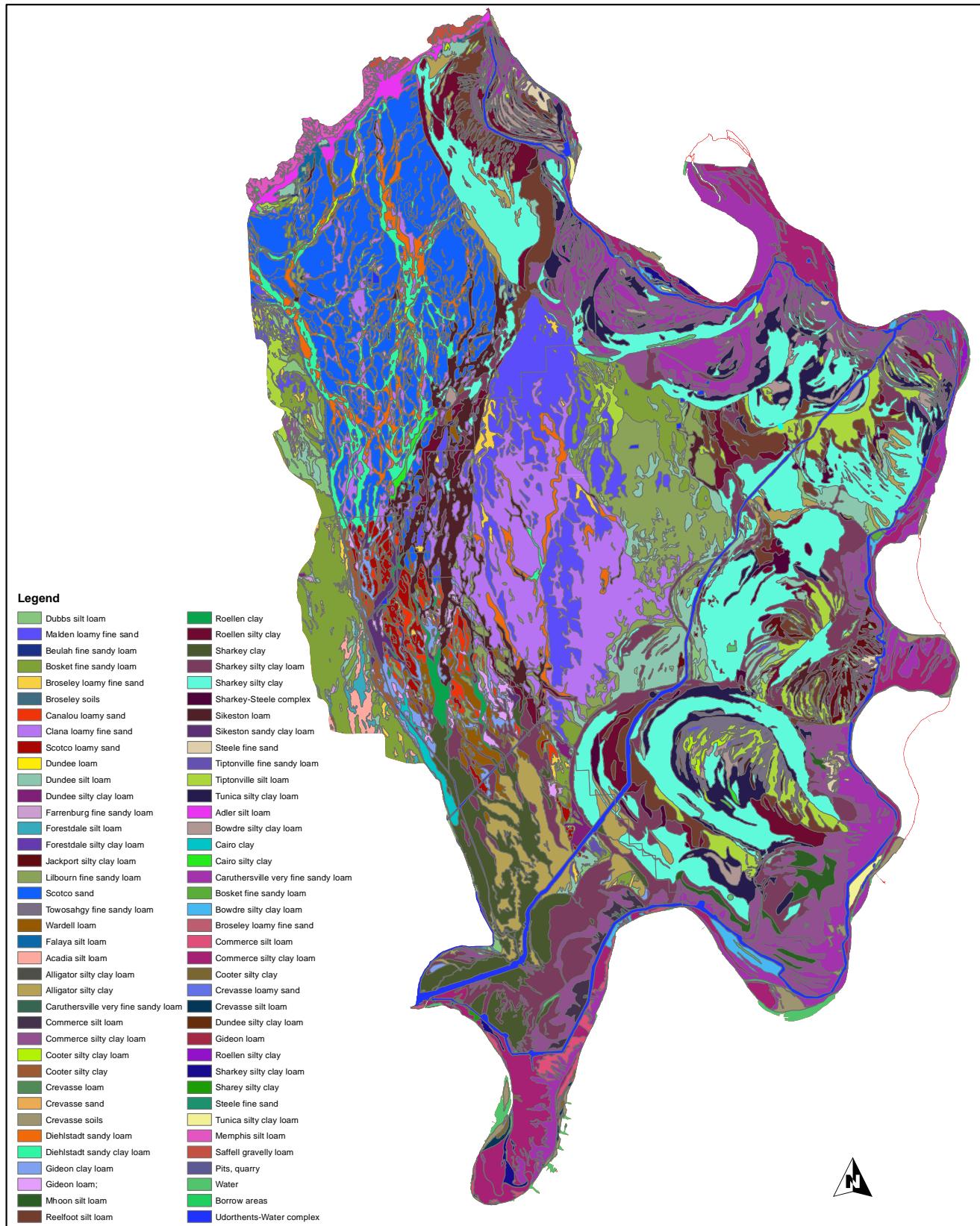


Figure 8. Soil types in the SJNM (from USDA SSURGO).

wide, with occasional high discharge occurring even in late summer and fall (Fig. 14). Mean annual discharge also exhibits alternating patterns of low vs. high river levels and that the system appears to gradually be getting wetter (Fig. 15).

Overbank flooding of the Mississippi River (in association with Ohio River flows) into the SJNM prior to the presence of mainstem-river and interior-floodplain levees undoubtedly followed natural seasonal and annual patterns of alternating high vs. low and wet vs. dry discharge and precipitation levels locally and in the watershed above the region. Unfortunately, historic Mississippi River stage-discharge correlations for the SJNM are not available for mid-late 1800s periods. However, mean monthly water elevations in the St. John's Bayou Basin and New Madrid Floodway from 1943 to 1974 describe rising and falling Mississippi River water levels and annual average periods of inundation by elevation (Tables 1, 2). Analyses of this regional stage-elevation information and known overbank flooding levels of the Mississippi River at Thebes (494,000 cubic feet/second (cfs), a 33 feet gauge reading, and 300 feet NGVD29 elevation) and New Madrid (34 feet gauge reading and 289.48 feet NGVD29) and the Ohio River at Cairo (50 feet gauge reading and 270.9 NGVD29), suggest that some spring backwater flooding into lower elevations < 280 feet NGVD29 including depressions, relict valley train channels, and abandoned river channels probably occurred almost every year. Higher flood events also caused regular, sometimes prolonged flooding, of higher elevations > 295 feet.

Existing flood frequencies in the St. John's Bayou Basin and New Madrid Floodway using 1943 to 1974 period of record information indicates over

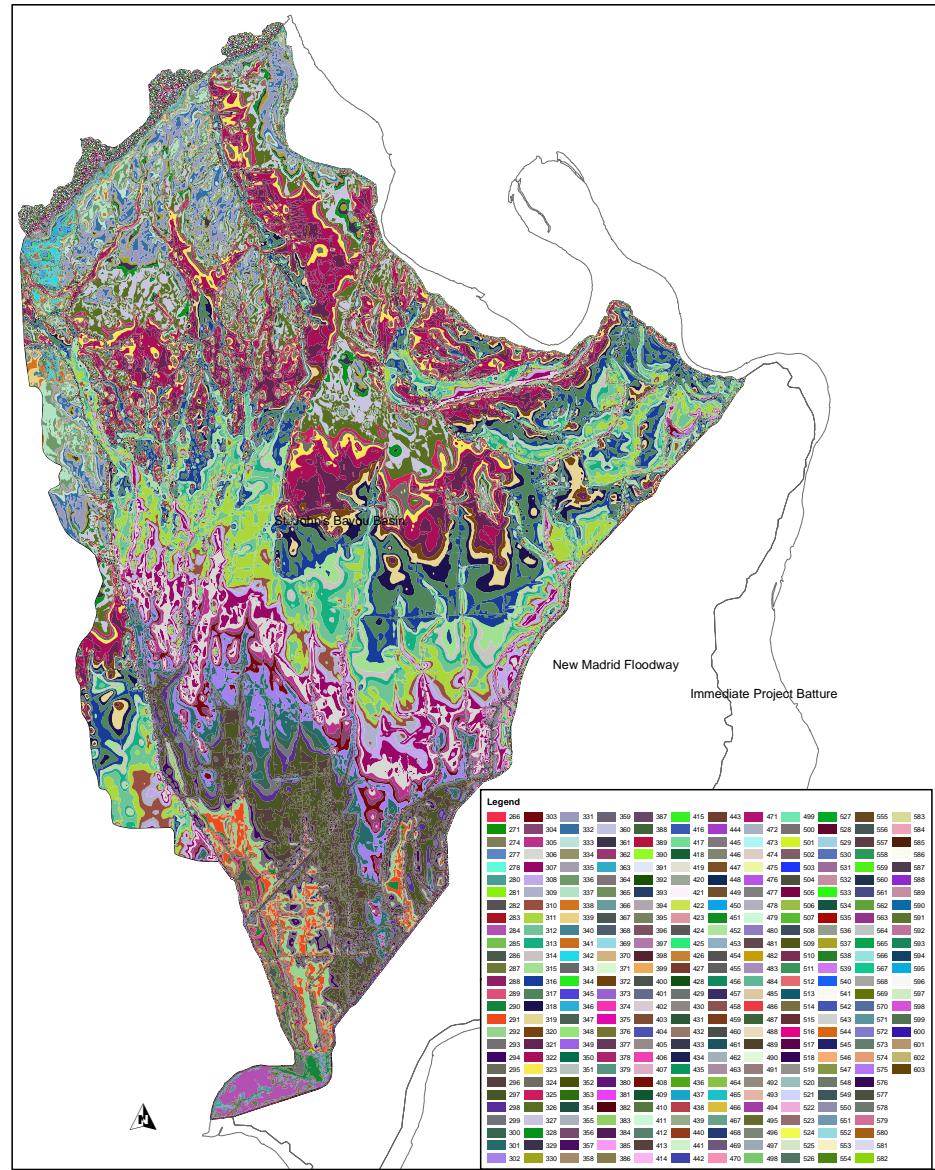


Table 1. Mean monthly surface water elevations in the St. John's Bayou Basin, 1943-1974 (from USACE 2009a).

Month	Existing Conditions No Pump Elev, Ft NGVD	Authorized Project Conditions	Alternative Project Conditions
		1000 cfs Pump Elev, Ft NGVD	1000 cfs Pump Elev, Ft NGVD
Jan	274.4	284.7	284.7
Feb	277.1	275.5	276.1
Mar	281.5	279.2	279.9
Apr	282.8	280.3	280.9
May	280.1	277.9	278.6
Jun	274.1	273.0	273.4
Jul	270.5	269.7	270.0
Aug	265.9	265.5	265.5
Sep	264.0	263.3	263.3
Oct	263.9	263.3	263.3
Nov	266.1	265.5	265.5
Dec	270.1	279.3	279.3
Mean	272.5	273.1	273.4

Table 2. Mean monthly surface water elevations in the New Madrid Floodway, 1943-1974 (from USACE 2009a).

Month	Existing Conditions Open & No Pump Elev, Ft NGVD	Authorized Project Conditions	Option 1 & Option 2 Closure & 1500 cfs Pump Elev, Ft NGVD	Option 3 Closure & 1500 cfs Pump Elev, Ft NGVD	Option 4 Closure & 1500 cfs Pump Elev, Ft NGVD
		Closure & 1500 cfs Pump Elev, Ft NGVD	282.3	282.3	282.7
Jan	274.6	282.3	282.3	282.7	282.8
Feb	278.1	273.1	274.8	275.2	275.3
Mar	282.2	274.9	277.5	277.8	277.8
Apr	283.7	275.7	278.5	278.6	278.6
May	280.0	275.0	277.2	277.2	277.2
Jun	274.5	272.3	273.3	273.4	273.5
Jul	270.7	269.5	270.2	270.3	270.4
Aug	265.9	265.7	265.8	266.3	266.6
Sep	264.0	264.0	264.0	265.1	265.6
Oct	264.4	264.3	264.3	265.5	265.9
Nov	266.1	265.9	266.0	266.9	267.2
Dec	269.9	277.6	277.6	279.0	279.3
Mean	272.8	271.7	272.6	273.2	273.3

levels occurred at New Madrid from December to February in the 60 year period 1939-40 to 1998-99 (Heitmeyer 2006).

Surface inundation and water elevations in the SJNM are not totally dictated by overbank or backwater flooding of the Mississippi River and its tributaries. The relatively porous nature of geomorphic surfaces that contain deep sand stratigraphy layers (Saucier 1994) causes groundwater levels in many locations to rise and fall in correspondence to Mississippi River levels (Luckey 1985). Consequently, Mississippi River levels that are above floodplain land elevations can create a hydraulic pressure head sufficient to cause groundwater to move from the river into and through subsurface land/gravel layers and discharge into depression areas. It is common for certain wetland depression sumps in the SJNM to be shallowly flooded when Mississippi River levels rise even if no local/regional precipitation has occurred for some time.

The SJNM is underlain by consolidated aquifers of Paleozoic age and unconsolidated aquifers of Mesozoic and Cenozoic age (Luckey 1985). The older McNairy aquifer ranges from 0 to 600 feet thickness in southeast Missouri and is > 1,000 feet below the land surface in the SJNM. This aquifer has a large artesian head and low iron and hardness concentration (Luckey 1985). The Wilcox Group lies < 300 feet below the surface and is up to 600 feet thick in the region. This aquifer is recharged from the overlying alluvial aquifer near the subcrop of the Wilcox Group. The alluvial aquifer is 100-200 feet thick and is locally capable of yielding more than 3,000 gallons/minute from wells. The aquifer is recharged from local precipitation and the Mississippi River flows and discharges by evapotranspiration and to the surface water system. The potentiometric surface of the alluvial aquifer is near the ground surface in many SJNM locations (Fig. 18).

VEGETATION COMMUNITIES

Paleoclimate Vegetation

During the late Wisconsin full-glacial interval (ca. 18,000 BP), the Upper MAV including the SJNM was covered mostly by boreal forest communities (Delcourt and Delcourt 1981, Delcourt et al. 1999). Apparently, a Spruce-Jack Pine-Willow forest type was present on the Valley Train braided stream terrace geomorphic surfaces of the region that was created by glacial meltwater flowing down the Mississippi and Ohio River corridors. Post glacial warming of the region about 14,000 BP caused the jack pine-dominated community in the Upper MAV to recede northward, however some evidence suggests that considerable Spruce-Willow communities were retained at least in areas east of Crowley's Ridge in Missouri (Delcourt et al. 1999). By 12,000 BP, warming temperatures allowed expansion of Oak-Hickory forests onto SJNM abandoned stream terraces. Subsequently, by 10,000 BP vegetation in the region had shifted to temperate to warm temperate types and a Sweetgum-Elm forest type perhaps similar to contemporary Intermediate BLH communities (see below) apparently occupied areas along the Mississippi River channels; some giant cane (*Arundinaria gigantea*) also was present on natural levee locations. Willow (*Salix sp.*) and other early succession tree species including cottonwood (*Populus deltoids*), sycamore (*Platanus occidentalis*) and maple (*Acer rubrum* and *Acer saccharinum*) (similar to the contemporary Riverfront Forest - see below), occupied newly scoured and regularly inundated areas along the active river channels (Delcourt et al. 1999). Bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) were present along with water tolerant shrubs occupied edges of abandoned channels and other deeper depressions including relict Valley Train channels. An Oak-Hickory forest similar to the contemporary High BLH communities appears to have expanded

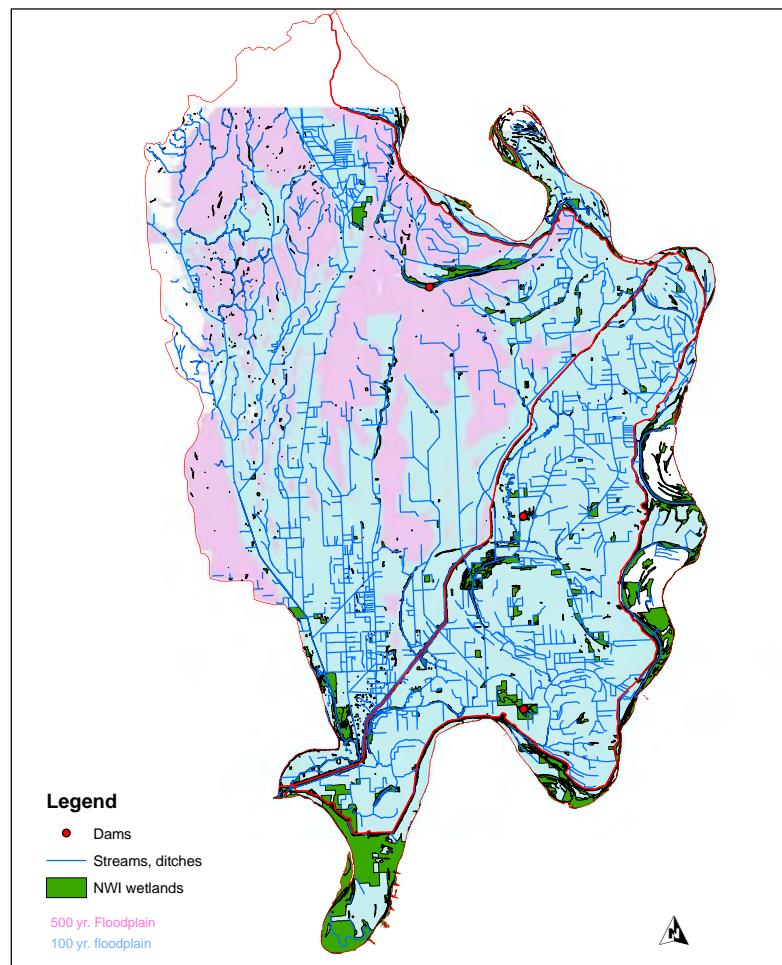


Figure 10. 100- and 500-year floodplain designation, streams and ditches, and certain forest areas delineated by the USFWS National Wetland Inventory in the SJNM.

onto higher elevation braided stream terraces at this time.

Beginning about 8,000 BP, continental climate warmed and dried and created the "Hypsithermal" or "Altithermal" period through about 4,000 BP (Saucier 1994, Delcourt et al. 1999). Drought-tolerant tree species expanded and most of the Oak-Hickory forest that had previously dominated higher elevations

Table 3. Existing flood frequencies (annual probability of flood recurrence) and inundated acres in the St. John's Bayou Basin and New Madrid Floodway (from USACE 2009a).

Event (year)	St. Johns Bayou Basin (acres)	New Madrid Floodway (acres)	Total
2	10,056	17,316	27,372
5	30.032	35,381	65,413
10	34,155	53,519	87,674
25	40.073	70,108	110,181
30+	55,000	75,078	130,078

probably shifted to a Savanna community with interspersed Prairie occurring on higher and drier elevations and soils, especially the Sikeston Ridge, interfluve Ps dune areas in older Valley Train complexes, and on the Charleston Fan. Wetter areas along the Mississippi River probably contained a diverse BLH community likely dominated by sweetgum (*Liquidambar styraciflua*), elm, ash, and willow with giant cane present on natural levees and some floodplain ridges (Delcourt et al. 1999). Bald cypress and water tupelo also apparently remained in floodplain depressions and abandoned channel locations.

Starting about 4,000 BP, climate in the SJNM moderated to a milder and wetter condition (Delcourt et al. 1999). The Sweetgum-Elm forest apparently re-expanded onto lower floodplain terraces and Riverfront Forest communities widened along active river channels. A diverse Terrace Hardwood-type Forest community likely expanded on higher elevation terraces and Prairie and Savanna areas likely decreased in extent at this time. The continuous channel migrations of the Mississippi River in the SJNM undoubtedly shifted the positions of Holocene floodplain vegetation communities regularly as water flow pathways, sediment, and scouring actions reworked and redistributed soils and water regimes. By about 1,000 BP certain portions of higher elevations in the SJNM apparently were covered by perennial grass and old field vegetation (Delcourt et al. 1999). These areas may have been sites disturbed or farmed by Native people and represented succession of abandoned fields (Lafferty and Price 1996, Lafferty 1998).

Presettlement Period Vegetation

The heterogeneity of geomorphic surfaces, soils, and topography in the SJNM in the 1700s created diverse and highly interspersed vegetation communities distributed across elevation and hydrological gradients (Fig. 19). Major natural community/habitat types that historically were present in the SJNM included: 1) the main channel and islands of the Mississippi River and major tributaries, 2) river “Chutes” and “Side Channels”, 3) Bottomland Lakes often

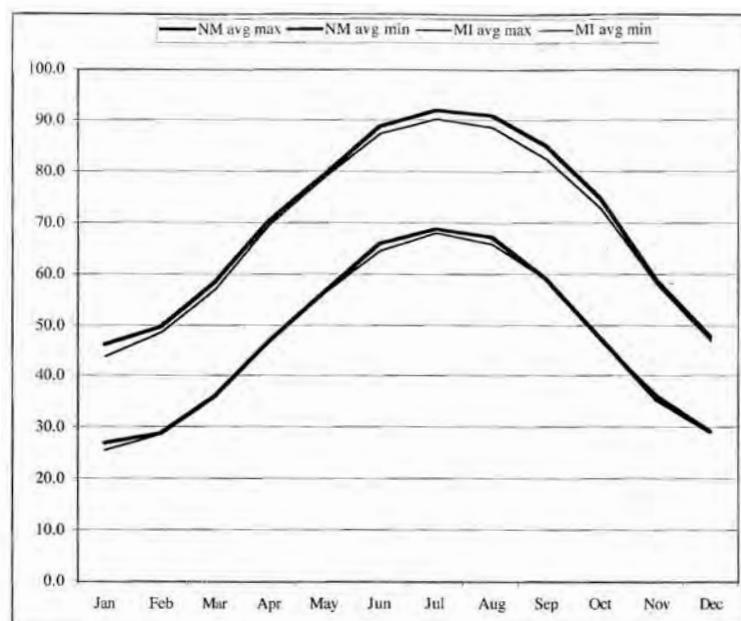


Figure 11. Average daily minimum and maximum temperatures for the SJNM (adapted from Buchner et al. 2009).

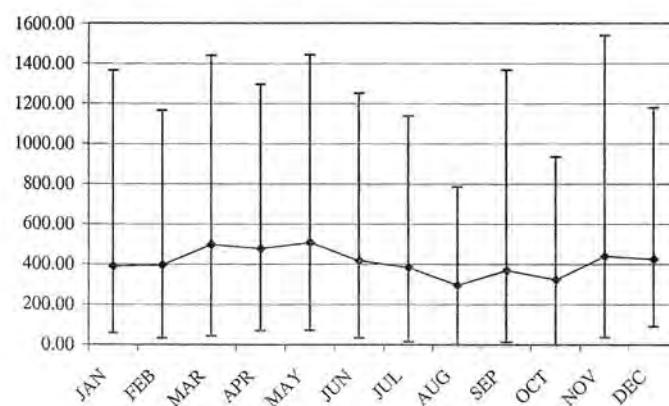


Figure 12. Mean monthly precipitation and range at New Madrid, Missouri (from Papon 2002).

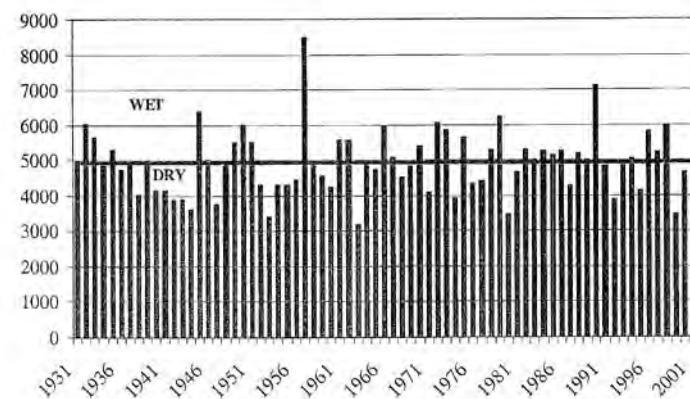


Figure 13. Annual precipitation and long-term mean precipitation at New Madrid, Missouri 1931-2001 (from Papon 2002).

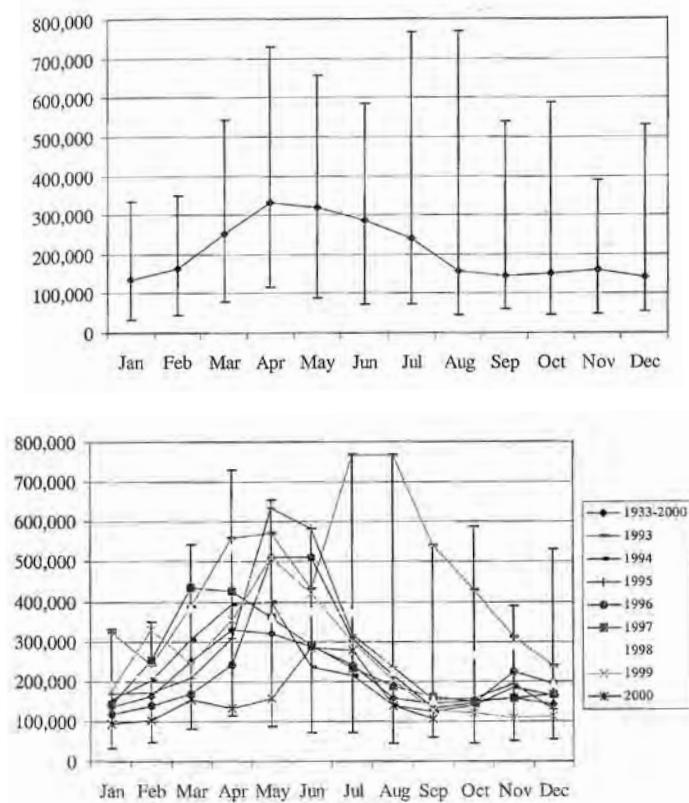


Figure 14. Mean monthly discharge of the Mississippi River at Thebes, Illinois 1933-2000 (from Papon 2002).

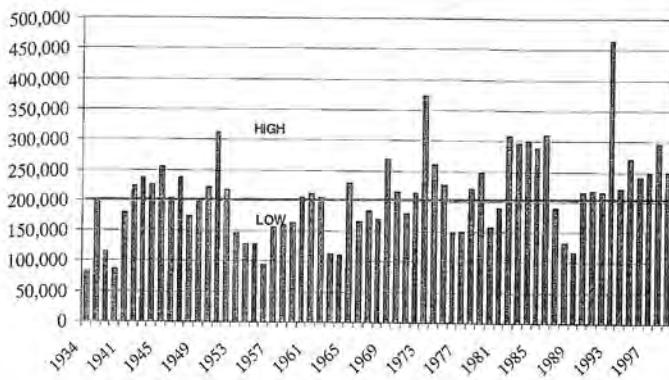


Figure 15. Mean annual discharge and long-term mean of the Mississippi River at Thebes, Illinois 1934-2000 (from Papon 2002).

referred to as oxbows or abandoned channel depressions, 4) Riverfront Forest, 5) BLH Forest, 6) Terrace Hardwood Forest, 7) Slope Forest, 8) Sand Prairie, and 9) Savanna (Nigh and Schroeder 2002, Nelson 2005). Lists of fauna and flora for these habitats are provided in Terpening (1974), Nelson (2005), and Heitmeyer et al. (2006).

The main channels of the Mississippi River and its major tributaries (e.g., Black Bayou, St. John's

Bayou) contain open water with little or no plant communities other than phytoplankton and algae (Theiling 1996). During low river levels in late summer and early fall, some river Chutes and Side Channels become disconnected from main channel flows and have stagnant water that supports sparse herbaceous "moist-soil" plants that germinate on exposed mud flats. During high river flows Chutes and Side Channels become connected with the main channel and scouring action of river flows prevents establishment of rooted plants in these habitats. The extent and duration of river connectivity is the primary ecological process that controlled nutrient inputs and exports, primary and secondary productivity, and animal use of Chutes and Side Channels. A wide variety of fish historically were present in the Mississippi River and tributary rivers and their Side Channels (e.g., Pfleiger 1975), and these habitats also were used by many amphibians, a few aquatic mammals, and some water and shorebirds (Smith 1996). Many remnant and active river chutes and side are present in the SJNM; representative sites include those around Wolf Island, Seven Island, along Donaldson's Point, and Islands 2, 3, and 4.

Few large permanent "islands" historically occurred within the Mississippi River or tributary channels in the SJNM, but "bars" were common on the edges of the Mississippi River channel, especially on the downward side of major bends (Fig. 20, Mississippi River Commission 1881, 1893-1904, Brauer et al. 2005). Most "islands" in the SJNM actually were extensions of floodplain chute and bar geomorphic surfaces and usually were separated from the floodplain by narrow, often highly sedimented, older Side Channels. During dry periods these "islands" became extensions of terrestrial floodplain surfaces. Vegetation on islands and bars depends on size, configuration, and connectivity to banks (Turner 1936). The degree and duration of flooding and connectivity to either the river or floodplain controls ecological attributes and animal use of islands and river bars. Most islands and bars historically were 1-4 feet below adjoining floodplain elevations and were overtopped during annual high flow periods (Brauer et al. 2005). During floods, river bars often become extensively scoured or destroyed, and new bars subsequently are created in other locations. Vegetation on bars is mostly pioneering plants that germinated on newly deposited alluvium. Annual herbaceous plants and seedlings of cottonwood, sycamore, and willow

are the most common plants. Larger islands in the SJNM including Wolf, Seven, and Powers Islands contained Riverfront Forest communities with some aquatic and herbaceous wetland plants in interior swales and sloughs.

Bottomland Lakes were present throughout the SJNM during the Holocene period and occupied abandoned Mississippi River channels (Saucier 1994). The location, age, and size of Bottomland Lakes determined depth, slopes, and consequently composition and distribution of vegetation communities. Bottomland Lakes in the SJNM historically were surrounded by BLH Forest and usually contained embedded or narrow bands of Bald cypress/water tupelo and/or shrub/scrub (S/S) vegetation along their edges (Heitmeyer 2008:19). S/S communities represent the transition area from more herbaceous and emergent vegetation in the aquatic part of Bottomland Lakes to higher floodplain surfaces that support trees. S/S habitats typically are flooded a few inches to 2-3 feet deep for extended periods of each year except in extremely dry periods. S/S habitats in the SJNM are dominated by buttonbush (*Cephalanthus occidentalis*), swamp privet (*Forestiera acuminata*), and willow. A natural levee usually is present along the edges of Bottomland Lakes and these areas support diverse composition less water tolerant forest species as a unique High BLH type (see below). The ends of some Bottomland Lakes contain Riverfront Forest species that germinate on coarse-grain materials that had “plugged” the old abandoned channel (Saucier 1994). Representative remnant bottomland lake ecosystems in the SJNM include more recent larger abandoned channels at Ten Mile Pond and Robert G. Delaney Lake CA's and smaller older sites are present near the Eagle's Nest USDA Wetland Reserve Program (WRP) site in Mississippi County. Water regimes are managed on each of these sites, but vegetation communities still contain the range of open water, S/S, Bald cypress/water tupelo, and seasonal herbaceous edge habitats. Few, if any, bottomland lakes retain natural hydrologic regimes.

Most newer and deeper Bottomland Lakes in the SJNM during the Presettlement period probably had central areas of permanent “open water” that contained abundant aquatic “submergent” and “floating-leaved” vascular species such as pondweeds (*Potamogeton sp.*), coontail (*Ceratophyllum demersum*), water milfoil (*Myriophyllum sp.*), American lotus (*Nelumbo lutea*), spatterdock (*Nuphar luteum*), and duckweeds (including *Lemna*, *Spirodella*, *Wolffia*) (Heitmeyer

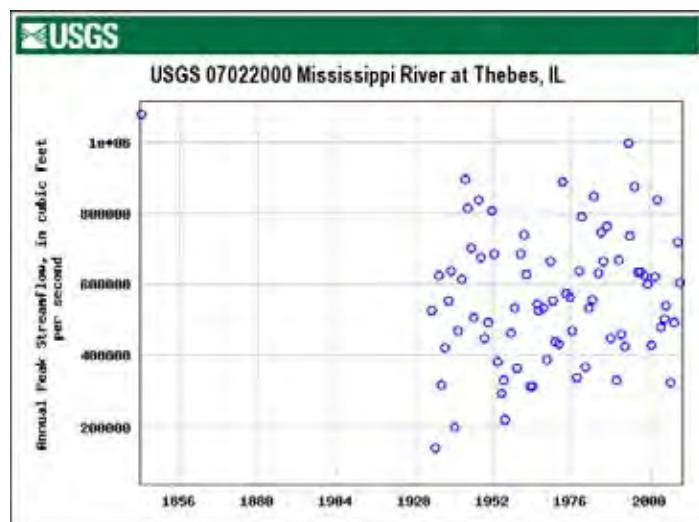


Figure 16. Peak annual streamflow (cubic feet/second) of the Mississippi River at Thebes, Illinois 1930-2009 (from <http://nwis.waterdata.usgs.gov>).

2008). The edges of these lakes typically dry for short periods during summer and contain extensive herbaceous wetland vegetation and minor components of emergent wetland plant species. Emergent vegetation in these areas includes arrowhead (*Sagittaria sp.*), cattail (*Typha latifolia*), rushes, river bulrush (*Scirpus fluviatilis*), sedges (*Carex sp.*), and spikerush (*Eleocharis sp.*). Herbaceous vegetation is dominated by smartweed (*Polygonum sp.*), millet (*Echinochloa sp.*), panic grass (*Panicum dichotomiflorum*), sprangletop (*Leptochloa sp.*), sedges, spikerush, beggartick (*Bidens sp.*), and many other perennial and annual “moist-soil” species. The distribution of emergent and herbaceous communities in Bottomland Lakes depended on length and frequency of summer drying. In drier years, herbaceous communities would have expanded to cover wide bands along the edges of Bottomland Lakes, while in wetter periods herbaceous plants were confined to narrow bands along the edges of deeper open water.

Bottomland Lakes support a high diversity of animal species. Historically, fish moved into these lakes for foraging and spawning (Jackson 2005) when they became connected with the Mississippi or Ohio Rivers during flood events. Many fish subsequently moved back into the main channel when flood water recedes or after they spawn or fatten during flood events; some fish then remain to populate the deeper lakes (e.g., Sparks 1995). Bottomland Lakes also support high density and diversity of amphibian and reptile species and some species, such as turtles, move into and out of these lakes similar to fish (e.g., Tucker 2003). Aquatic mammals regularly

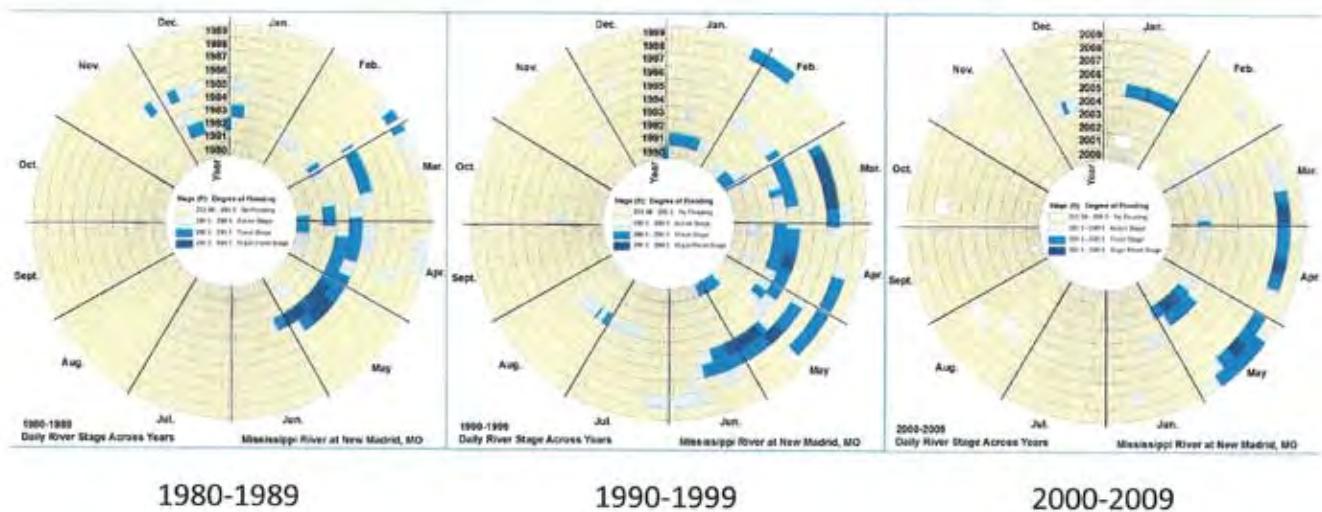


Figure 17. Ring-map of periods of overbank flooding duration of the Mississippi River at New Madrid by decade from 1980-89 to 2000-09.

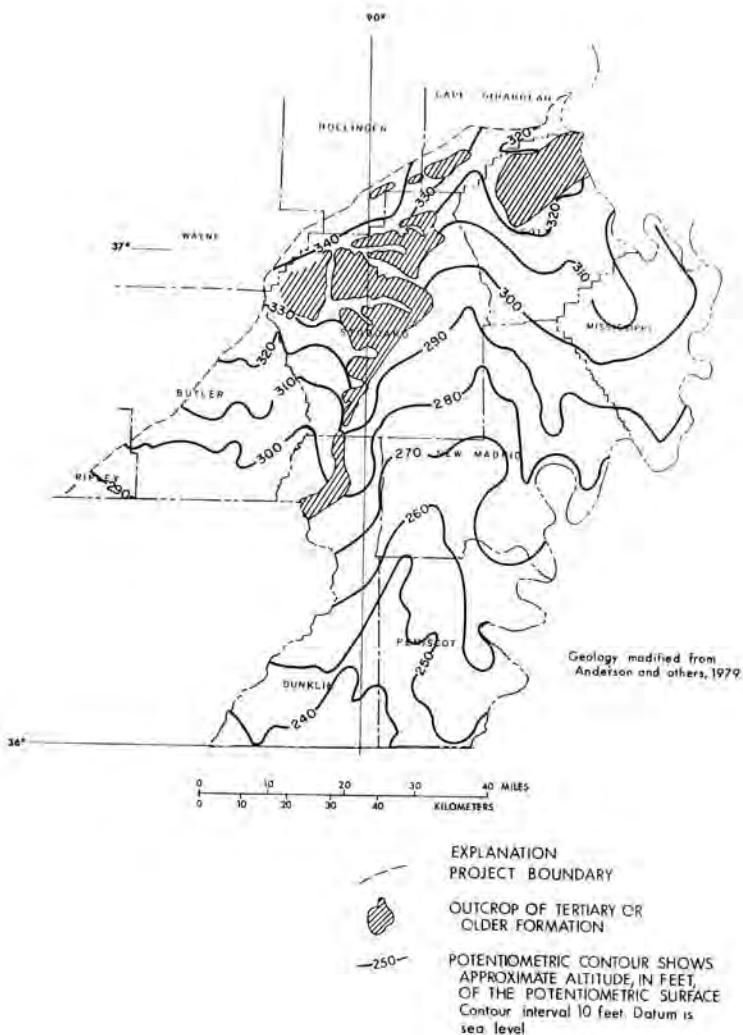


Figure 18. Generalized potentiometric surface of the alluvial aquifer in southeast Missouri during spring 1976 (modified from Luckey 1985).

use Bottomland Lakes and more terrestrial mammals travel in and out of these areas for seasonal foraging, breeding, and escape cover during dry periods. Bird diversity in these lakes is high, and extremely high densities of waterfowl, rail, shorebirds, and wading birds use these habitats for foraging, nesting, and resting sites (Heitmeyer et al. 2005).

Forest covered much of the SJNM and other nearby Mississippi River floodplain areas during the late 1700s (Hutchins 1784, Collot 1826, GLO 1817-40, Nuttall 1823). The distribution of tree and woody shrub species was arrayed along geomorphic/topographic and hydrological gradients (e.g., Coulter 1904, Steyermark 1962, Hosner and Minckler 1963, Voight and Mohlenbrock 1964, Fredrickson 1978, Robertson et al. 1978, Leitner and Jackson 1981, Klimas 1987, Mohlenbrock 1989, Nelson 1997, Conner and Sharitz 2005). Generally, a continuum of Riverfront Forest, BLH and Terrace Hardwood communities was present from the edges of the Mississippi River channel to Sikeston Ridge (Fig. 19). These communities transcend the Riverfront Forest, Wet Bottomland to Mesic Bottomland Forest, and Bottomland Flatwood Forest categories described in Nelson (2005).

Riverfront Forest (also called “River-edge Forest” in some older botanical literature) was present on recently deposited and/or scoured coarse sediment chute and

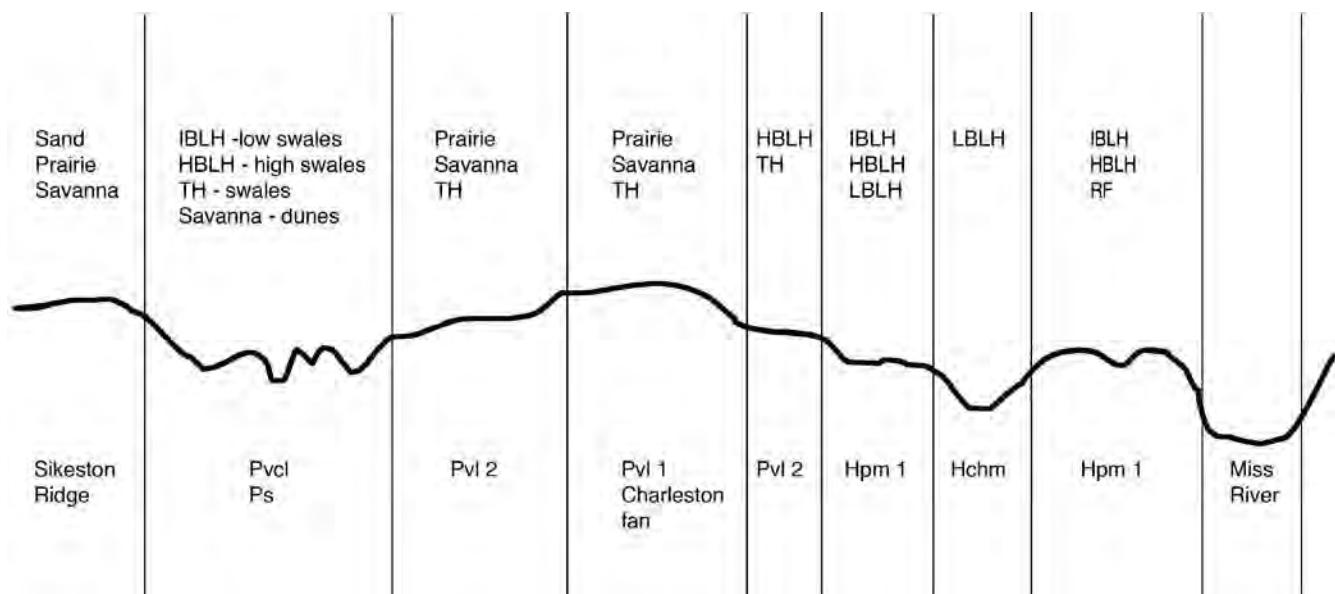


Figure 19. Cross-section schematic of vegetation community types across geomorphic and elevation surfaces in the SJNM. (See text for habitat and geomorphology acronyms.)

bar surfaces, some point bar areas near the current channel of the Mississippi River, and along the edges of some abandoned channels (Thomas 1841, Gregg 1975, Klimas 1987, Mohlenbrock 1989, Nelson 1997, Nelson 2005, Heitmeyer 2008). These geomorphic surfaces contain recently accreted lands and were sites where river flows actively scour and deposit silt, sand, gravel, and some organic debris. Soils under Riverfront Forests, especially on recently created chute-and-bar surfaces (Woerner 2003), are relatively young, annually overtopped by flood waters, highly drained, influenced by groundwater dynamics as the Mississippi River rises and falls, and often contain thin veneers of silt over sands and gravel. The most common soil under Riverfront Forest in the SJNM is Caruthersville sandy loam and Commerce silt loam (Fig. 8).

Riverfront Forest communities are dominated by early succession tree species and range from water tolerant species such as black willow (*Salix nigra*) and silver maple along the river channel and in low elevations and swales to intermediate water tolerant species such as green ash, cottonwood, sycamore, box elder, pecan, and sugarberry on ridges. Swamp white oak (*Quercus bicolor*) and pin oak occasionally are present in higher elevations in Riverfront Forest areas, but these species have high mortality during extended flood events and oak patches in historic Riverfront Forest communities probably were small and scattered (e.g., Hall

and Smith 1955, Bell and Johnson 1974, Black 1984, Nelson and Sparks 1998). Shrubs and herbaceous vegetation in Riverfront Forests is sparse near the Mississippi River but dense tangles of vines, shrubs, and herbaceous vegetation are present on higher elevations away from the river where alluvial silts were deposited. Typical shrub and vine species are poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), grape (*Vitis sp.*), and dogwood (*Cornus sp.*). Giant cane occasionally is present on these higher elevations, but repeated river flooding and scouring limit its occurrence and persistence (e.g., Gagnon 2007). The dynamic scouring and deposition in chute and bar areas also limits the tenure of many woody species except on the highest elevation ridges where species such as cottonwood and sycamore often become large mature stands (e.g., Hosner and Minckler 1963). Remnant, representative Riverfront Forest sites are present in many areas in the SJNM batture lands along the Mississippi River such as Seven Island and Wolf Island, the end of the Robert Delaney Lake CA, and other remnant river chutes in the floodplain.

Riverfront Forests are used by many animal species, especially as seasonal travel corridors and foraging sites. Many bird species nest in Riverfront Forests, usually in higher elevation areas where larger, older, trees occurred (Papon 2002). Arthropod numbers are high in Riverfront Forests during spring

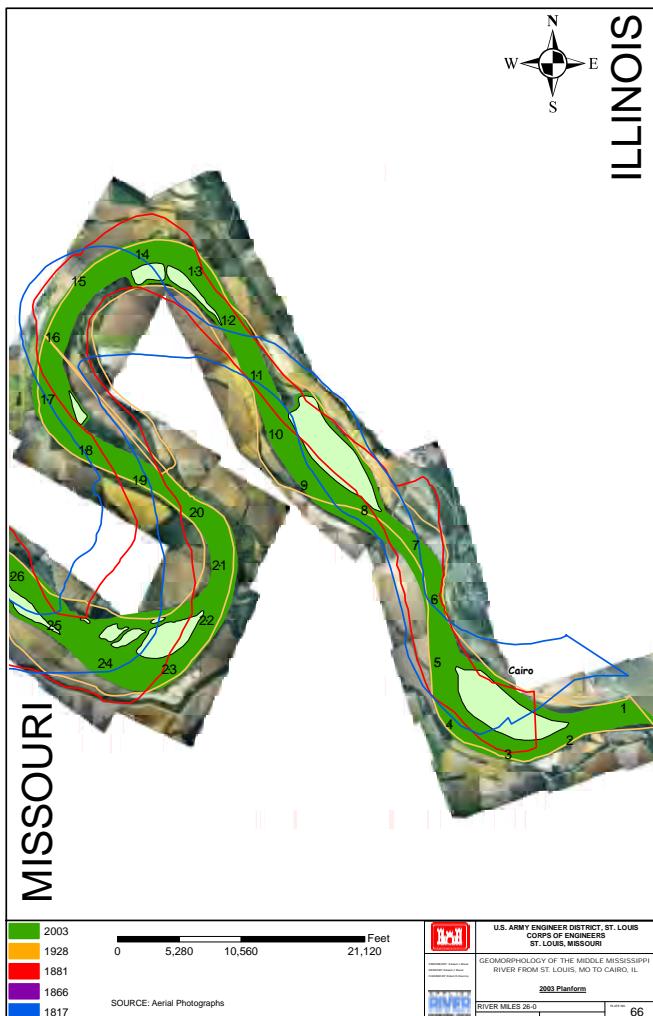


Figure 20. Location of bar and river chute habitats on the Mississippi River in 2003 in relation the channel position from 1812 to 2003 (modified from Brauer et al. 2005).

and summer and these habitats also contain large quantities of soft mast that is consumed by many bird and mammal species (e.g., Knutson et al. 1996). Few hard mast trees occur in Riverfront Forests, but occasional “clumps” of pecan or oak provide locally abundant nuts. The very highest elevations in chute and bar areas provide at least some temporal refuge to many ground-dwelling species during flood events (Heitmeyer et al. 2005).

BLH communities historically covered extensive areas of the SJNM, especially in the Holocene meander belt, and lower elevations of valley train channel complexes. Consequently BLH in the SJNM occurred in several soil types and contained diverse mixtures of species (Conner and Sharitz 2005, Heitmeyer et al. 2006). Tree species composition in BLH communities in the SJNM can be separated along elevation and flooding gradients (Fig. 21). Low

BLH communities occur in floodplain sites that range from being flooded for extended periods each year, and occasionally year round, to being flooded for 4-6 months in winter and spring. The lowest elevations in the SJNM historically contained bald cypress, water locust (*Gleditsia aquatica*), pecan, water elm and water tupelo (e.g., Coulter 1904). At slightly higher elevations in Low BLH communities slightly less water tolerant trees such as overcup oak, green ash, red maple, and pecan with scattered pin oak are present. Woody shrubs in Low BLH sites include buttonbush, swamp privet, and planer tree/water elm (*Planera aquatica*). Many understory vines typically are present in Low BLH communities and include rattan vine (*Berchemia scandens*), Ladies' eardrops (*Brunnichia ovata*), greenbrier (*Smilax retundifolia*), crossvine (*Bigonia capreolata*), and poison ivy. Ground herbaceous cover usually is sparse in Low BLH because of extended flooding, but sedges, beggar ticks, swamp smartweed (*Polygonum hydropiperoides*), water pepper (*Polygonum hydropiper*), butterweed (*Diodia teres*), and rice cutgrass (*Leersia oryzoides*) often are abundant during dry periods. Low BLH historically was present in deeper point bar swales, older abandoned channels and river chutes, backswamps, and depressions behind small natural levees (e.g. Coulter 1904, Steyermark 1962, Nelson 1997). Soils in Low BLH communities in the SJNM are Sharkey, Jackport, and Alligator clays. Remnant examples of Low BLH in the SJNM include areas on Ten Mile Pond and Robert G. Delaney CA's, areas near the Eagle's Nest WRP site, and scattered depressions on private lands.

Intermediate BLH (similar to the Wet-Mesic Bottomland Forest of Nelson 2005) in southeast Missouri occurs mainly in floodplain areas that typically flood 2-4 months annually during the dormant season and into early spring (Heitmeyer et al. 2006, Heitmeyer 2008). Soil saturation in Intermediate BLH often becomes extended for 3-4 months in wet years, but surface flooding may not occur in extremely dry years. Soils in Intermediate BLH in the SJNM are dominated by silty-clay loams (Appendix A). Tree species composition in Intermediate BLH is diverse and includes pin oak, Nuttall oak (*Quercus Nuttalli*), swamp chestnut oak (*Quercus michauxii*), bur oak (*Quercus macrocarpa*), green ash, slippery elm (*Ulmus rubra*), pecan, sugarberry, American elm, box elder, sweetgum, and some widely scattered swamp white oak. Small depressions in Intermediate BLH zones, such as vernal pools, include overcup oak, green ash, maple, and pecan. Giant cane is occa-

sionally present in some floodplain forest locations, mostly on higher ridges (Brantley and Platt 2001, Gagnon 2005). Common privet (*Ligustrum vulgare*), honeysuckle (*Ionicera japonica*), grape, trumpet creeper (*Campsis radicans*), greenbrier, and poison ivy are common understory plants in Intermediate BLH. Early explorers often commented on the relatively “impenetrable” nature of these floodplain forests (e.g., Collot 1826). The Intermediate BLH in the SJNM resembles in many ways the Floodplain Forests, with low oak composition, that historically covered large expanses of the Middle Mississippi River Corridor floodplain on point bar surfaces and along tributary streams (Hus 1908, Telford 1927, Gregg 1975, Robertson et al. 1978, Klimas 1987, Brugam and Patterson 1996, Nelson 1997, Yin 1999, Heitmeyer 2008). Typical Floodplain Forests in northern parts of the Mississippi River Valley represent a transition zone from early succession Riverfront Forest located on coarse-sediment chute and bar surfaces to BLH forests that occur in silt-clay soils in floodplain depressions. Northern Floodplain Forests typically develop on mixed sandy loam soils where older point bar “ridge-and-swale” topography occurred. Most of these older point bar surfaces were within the 1-2 year flood frequency zone. Some botanical literature calls this forest type the “sugarberry-elm-sweetgum” zone (e.g., Lewis 1974, Gregg 1975). Remnant examples of Intermediate BLH are present in Big Oak Tree State Park, forested areas northwest of Ten Mile Pond CA, a few privately-owned relict channels in Pvcl surfaces, and slough banks and natural levees along the mainstem Mississippi River levee.

High BLH communities in the SJNM similar to the Mesic Bottomland Forest category in Nelson (2005) are present in floodplain, natural levee, and terrace locations that flood for up to a few weeks annually during most years; slightly longer duration flooding occurs during

wetter periods and during major Mississippi River flood events. Some High BLH sites typically are dry for several years during dry periods, but soils in High BLH usually are saturated for some periods annually. Soils under High BLH communities in the SJNM are mainly silt loams in Hpm1 surfaces (except natural levee sites) and sandy loams on terraces, relict Valley Train channels, and natural levees (Appendix A). Dominant plant species in High BLH include willow, pin, and cherrybark oak (*Quercus pagoda*); shagbark (*Carya ovata*) and shellbark (*Carya laciniosa*) hickory; sweetgum; and American elm. Some High BLH on the edges of Pv1 surfaces probably contained scattered post oak and winged elm. High BLH on natural levees often is somewhat distinct from lower floodplain or terrace locations in part because of sandy soils and includes sycamore, cottonwood, willow, pecan, box elder, sug-

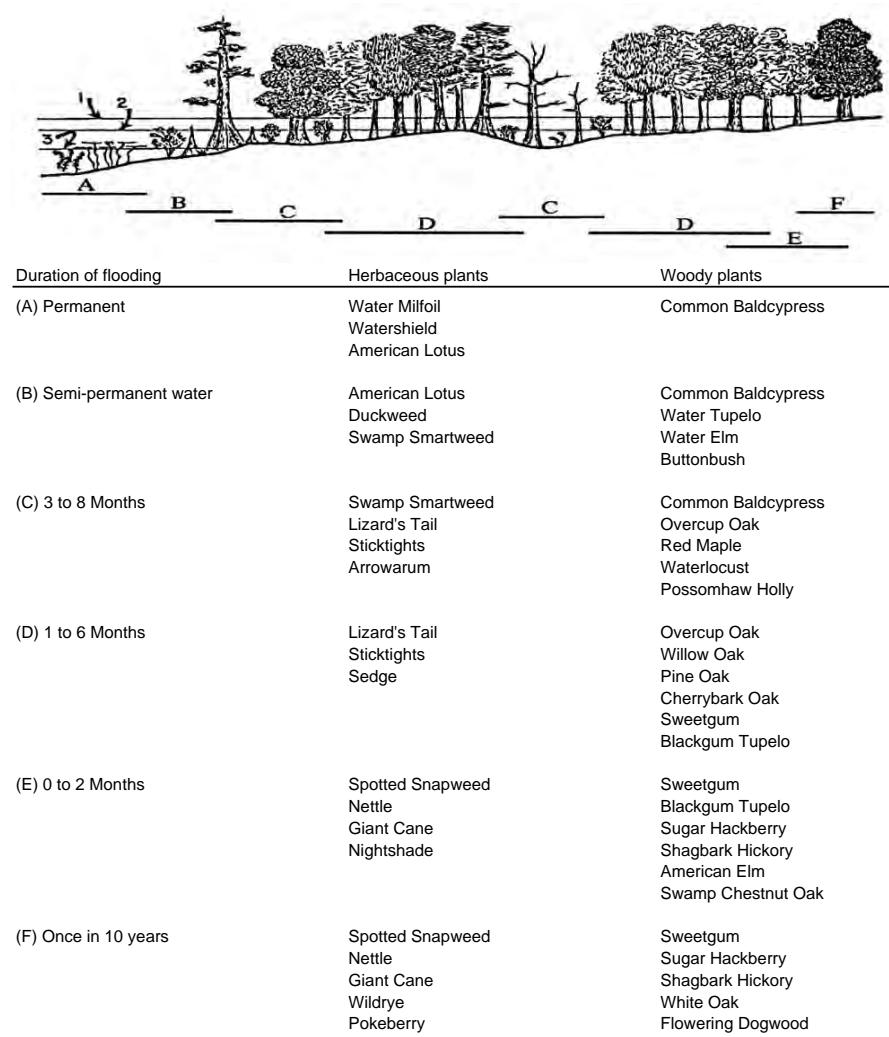


Figure 21. BLH species composition across elevation and hydrological gradients (modified from Fredrickson and Batema 1982).

arberry, willow and water oak (*Quercus nigra*), and winged elm. Herbaceous cover often is extensive in historic High BLH sites where understory plants include dense stands of poison ivy, climbing dogbane (*Trachelospermum dirrorme*), crossvine, and Virginia and trumpet creeper. Giant cane patches often are present in many remnant BLH habitats in the MAV, usually on the higher ridges or older natural levee surfaces (Gagnon 2007). Only a few scattered remnant High BLH sites remain in the SJNM on private lands and ridges on the northern Charleston Fan and inside older point bar meander scrolls and natural levees.

Animal diversity is high throughout BLH community types because of the deep alluvial soils, seasonal flooding regimes, diverse plant communities, high structural complexity, and rich detrital food bases (Heitmeyer et al. 2005). Most foods within BLH become available in seasonal “pulses” that provide many different types of nutrients used by many trophic levels and within many niches. Consequently, this community supported large numbers of animal species and individuals. The primary ecological process that sustain BLH communities and their productivity is seasonal, mostly dormant-season, flooding. Regular disturbance events also help sustain this ecosystem through periodic extended flooding or drought, wind storms, and rarely fire in at least the higher elevations.

Terrace Hardwood Forest historically occurred in the SJNM on the edges of Pvl and Pve surfaces where overbank and backwater flooding from the Mississippi River was rare (> 100 year recurrence elevations) and soils graded into sandier Entisols including Clana, Bosket, Scotco, Broseley, Canalou, Farrenburg, and Lilbourne types (Appendix B). These communities are often called “Flats” (Klimas et al. 2009) or “Bottomland Flatwoods” (Nelson 2005) because they occur on old high elevation terraces that often are subject to ponding of rainwater or short duration local stream flooding. During extremely high Mississippi River floods, these high terraces are inundated, usually for short periods in spring. Dominant canopy trees in Terrace Hardwood Forests are pin oak, cherrybark oak, post oak, willow oak, hickory, winged elm, and persimmon (*Diospyros virginiana*) (Nelson 2005). Trumpet creeper and climbing dogbane are common shrubs and sedges, goldenrod (*Solidago sp.*), bedstraw (*Galium asprellum*), spider lily (*Lycoris sp.*), and wood sorrel (*Oxalis acetosella*) are common herbaceous species. As with High BLH, almost all Terrace Hardwood

Forest has been destroyed and converted to agriculture in the SJNM, but a few small remnants exist around the town of East Prairie and on private land in Pvl1 and Pvl2 surfaces.

A small area of Slope Forest apparently occurred in the SJNM on alluvial fans that eroded from the Commerce Hills in the extreme north part of the region. Slope Forests contain unique mixes of trees representing both upland and floodplain communities that occur adjacent to alluvial fans. Some authors refer to this habitat as the “shatter zone” between upland and river valley floor plant associations (Gregg 1975). The diverse tree species present in Slope Forests includes hickory, sugarberry, swamp white and swamp chestnut oak, white oak (*Quercus alba*), bur oak, southern red oak (*Quercus falcata*), black walnut (*Juglans nigra*), hawthorn (*Crataegus sp.*), persimmon, honey locust (*Gleditsia triacanthos*), Kentucky coffeetree (*Gymnocladus dioica*), and slippery elm. Many other woody species are present in the understory and as occasional canopy trees. Herbaceous cover often is extensive in Slope Forest (Chmurny 1973, Gregg 1975), especially on the lowest elevations of alluvial fans and includes columbine (*Aquilegia Canadensis*), spikenard (*Aralia racemosa*), wild ginger (*Asarum canadense*), spring beauty (*Claytonia virginica*), pepperroot (*Dentaria laciniata*), cleavers (*Galium aparine*), sensitive fern (*Onoclea sensibilis*), sweet jarvil (*Osmorhiza Claytoni*), pokeberry (*Phytolacca Americana*), may apple (*Podophyllum peltatum*), great Solomon’s seal (*Polygonatum canaliculatum*), and false Solomon’s seal (*Smilacina racemosa*) (Zawacki and Hausfater 1969).

Slope Forests are not flooded except during extreme Mississippi River floods. Even during extreme floods, only the low elevation bottom parts of the alluvial fan slopes historically would have been inundated. Most water flows off alluvial fan slopes in a wide overland sheetflow manner and only minor drainages originate from these areas. Many alluvial fans have seep areas where upland groundwater exits. In the Prairie-Forest-Savanna transition sites that may have occurred in these northern SJNM areas (see discussion below) it is likely that some Savanna was present as narrow bands at the bottom of alluvial fan slopes and probably was maintained by occasional fire. Fire in these areas may have originated in either the higher elevation terrace (Pve, Pvl, Pvl1, Pvl2) or upland Commerce Hills. Soils in alluvial fans in the SJNM are unique erosional gravelly loams (Appendix A).

Many animals use Slope Forest and these sites also were preferred sites for Native American and early Anglo-European settlements (e.g., the town of Commerce, Missouri). These sites contained rich floral communities, multiple food types, and relief from periodic flooding and bothersome insects in the floodplains. These areas also provided natural sloping movement corridors from floodplains to uplands.

Prairies historically occupied extensive areas on the Sikeston Ridge and Charleston Fan in the SJNM (GLO 1817-40, Schroeder 1981). The exact composition of these prairies is unknown, but most probably were drier Sand-type prairies located on higher sandy ridges and new Pvl1 terraces (Schroeder 1981, Hendershott 2004, Nelson 2005). All historic Prairies in the SJNM were underlain by fine sandy loam Bosket and Malden soils (Appendix A). The distribution of Prairie in the SJNM probably was determined by the dynamic “line” of where: 1) fine sandy soils occurred, 2) floodwater ranged toward higher elevations in floodplains and 3) the elevation “line” where fires originating from uplands and higher elevations moved into the wetter lowlands (Nelson 2005). Historically, Sand Prairie vegetation was partly maintained by fire occurring at about 5-8 year intervals (e.g., Hendershott 2004) caused by lightning strikes or intentionally set by native people and by seasonal herbivory from elk (*Cervus canadensis*), bison (*Bison bison*), white-tailed deer (*Odocoileus virginianus*), and many rodents. This herbivory cropped and recycled prairie vegetation and also browsed invading woody shrubs and plants. Sand Prairie was characterized by little bluestem (*Schizachyrium scoparium*), splitbeard bluestem (*Andropogon ternaries*), broomsedge (*Andropogon virginicus*), fall witch grass (*Digitaria cognata*), bead grass (*Paspalum setaceum*), woolly three-awn (*Aristida lanosa*), sand dropseed (*Sporobolus cryptandrus*), sandbur (*Cenchrus longispinus*), tickseed coreopsis (*Coreopsis lanceolata*), nodding spurge (*Chamaesyce maculata*), sand milkweed (*Asclepias amplexicaulis*), and others. Several rare species occur in this habitat including Baldwin’s sedge (*Cyperus croceus*), Plukenet’s umbrella sedge (*Cyperus plukenetii*), many-spiked umbrella sedge (*Cyperus polystachyos* var. *texensis*), flatsedge (*Cyperus hystricinus*), St. John’s wort (*Hypericum adpressum*), warty panic grass (*Panicum verrucosum*), butterfly bush family (*Polypremum procumbens*), puccoon (*Lithospermum incisum*), sand milkweed (*Asclepias amplexicaulis*), and sand three-awn (*Aristida desmantha*).

Perennial plants of Sand Prairies tend to have narrow leaves and tiny hairs to limit water loss. Plants also tend to have deep roots and grow in tufts to reduce exposure to wind. Annual plants also have slender leaves and few branches. Animals using these prairies also have special adaptations or are usually only seasonal visitors. Two frogs well adapted to Sand Prairies are the Illinois chorus frog (*Pseudacris streckeri illinoensis*) and eastern spadefoot (*Scaphiopus holbrookii holbrookii*) (Johnson 2000). Both spend most months burrowing and feeding underground and they only come to the surface to breed during the wet spring months. Their eggs hatch faster, and tadpoles metamorphose faster than those of other frog species in Missouri. Northern (*Neocurtilla hexadactyla*) and prairie mole (*Gryllotalpa major*) crickets also live in Sand Prairies and similar to the frogs, live mostly underground. Bison and elk formerly were present in the region but apparently were extirpated by 1860 (Beckwith 1887 cited in Hendershott 2004). Other common upland species in these habitats are bobwhite quail (*Colinus virginianus*), grassland songbirds, fence lizard (*Sceloporus undulatus hyacinthinus*), white-tailed deer and rabbits.

At the higher elevations of the SJNM floodplain, especially on terraces, sand-type Prairie often transitioned into zones or patches of Sand Savanna (Nelson 2005). Soils under Sand Savanna are similar to Sand Prairie sites. Sand Savannas contain post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and black (*Carya texana*) and mockernut (*Carya tomentosa*) hickory as common tree species. The herbaceous layer of these Savannas contains species similar to Sand Prairies and is dominated by little bluestem. Rare plant species in these habitats are sand hickory (*Carya pallida*), corydalis (*Corydalis micrantha*), bluecurls (*Trichostema setaceum*), wooly three-awn, and umbrella sedges. The irregular occurrence of fire likely defined the upper boundary of Savanna and conversely, the lower elevation boundary that graded into Terrace Hardwood or High BLH was determined by a transition of soils to more loamy types and occasional backwater flooding from the Mississippi River. Given the position of Sand Prairie and Savanna, animal species common to both forest and prairie are present. These sites also were common camp or occupation sites for native peoples because of their higher, less flood prone, location; the presence of grasslands where small cultivation areas could be easily maintained; locally available wood for fires;

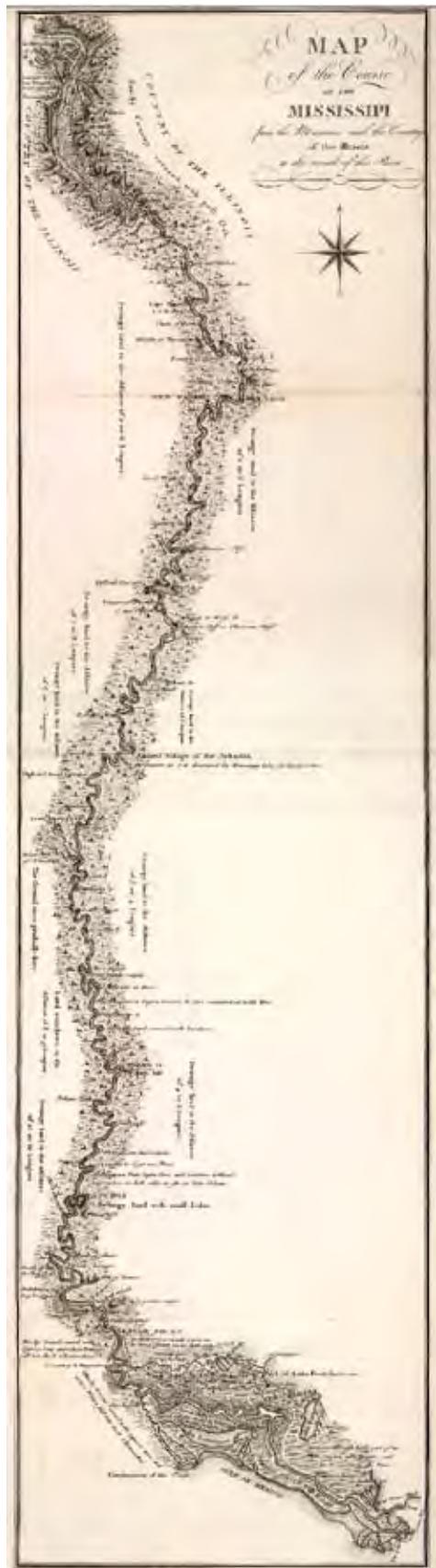


Figure 22. Map of the Middle Mississippi River corridor produced by Victor Collot in the late 1790s (from Heitmeyer 2008).

and natural travel corridors between uplands and floodplains (Lafferty and Price 1996). Few examples of prairie and savanna are present in the SJNM – most was converted to agricultural production in the 1800s. Representative Prairie and Savanna presently occur on small sites on Sikeston Ridge, Sand Ridge local cemeteries, and the Charleston Baptist Camp land in Scott County (Nigh and Schroeder 2002, Nelson 2005).

DISTRIBUTION AND EXTENT OF PRESETTLEMENT HABITATS

The exact distribution of specific vegetation communities (habitat types) in the SJNM prior to significant European settlement in the late 1700s is not known. However, the above discussion identified the many sources of information about the geography and distribution of major vegetation communities for the SJNM and similar nearby Upper MAV geomorphic regions. These data include historic cartography, botanical data and accounts, and general descriptions of landscapes from early explorers and naturalists. While the precise geography of early maps (e.g. river channel boundaries) is often flawed, these maps provide general descriptions of relative habitat types, distribution, and configuration.

Apparently, the first maps of the Mississippi River (and parts of its floodplain) in the SJNM were made during French governance of the region by the French cartographers Franquelin (produced in 1682), De L'sle (1703 and 1718), d'Anville (1746 and 1755), and Bellin (1755) (Wood 2001). When the British Regime succeeded French rule of the area in the mid-1700s, new maps of the Middle Mississippi River Valley including the SJNM were prepared. The first known British map was drawn by Philip Pittman in 1765 and it essentially was a compendium of the earlier French maps (Thurman 1982). Although it was not highly original, the Pittman map became the accepted “standard” for geography of the Middle Mississippi River region; subsequent maps expanded coverage and descriptions to lower course tributaries (e.g., the Ross map produced in 1867) and floodplains (Hutchins 1784). The Hutchins’ map relied heavily on Pittman’s map and his book “A topographic description of Virginia, Pennsylvania, Maryland, and North Carolina” published in 1778 contained the most accurate map of the Illinois Country at that time. The journal from Hutchins’ mapping trip and that of Captain Harry Gordon at the same period offered detailed description of many important floodplain features. Subsequent to Hutchins’ map was the excellent map of General Victor Collot prepared from field surveys in the late 1790s and published in 1826 (Fig. 22). This “Collot” map provided expanded notes and coverage of vegetation and larger wetlands in the SJNM floodplain and became the basis for additional maps and naturalist accounts of Nicolas de Finiels in the early 1800s (Ekberg and Foley 1989).

In the early 1800s, following American occupation and rule, the Mississippi River Valley including the SJNM was mapped by the U.S. General Land Office (GLO) to establish a geometric system of land ownership and governance (i.e., the Range-Township-Section system developed by Thomas Jefferson and codified in the Land Survey Ordinance of 1785). These GLO surveys established right-angle “section lines” in a geometric land grid system, and the surveyors also documented vegetation and “witness” trees at section corners and center points between the corners (GLO 1817-40). Consequently, the GLO maps and surveys established a “georeference” of locations and distribution of SJNM features including general habitat types (Fig. 23). GLO surveyors usually described vegetation communities in broad categories (e.g., forest, bottomland, prairie) and grouped witness trees in general taxonomic groups (e.g., black vs. white oak). Consequently, considerable interpretation often is needed to determine the exact species composition that was noted. Most likely, the “black oaks” described in GLO notes for the Middle Mississippi River Regional Corridor were “red oak” species such as pin, willow, and cherrybark oaks because true black oak (*Quercus velutina*) does not grow in floodplains (Settergren and McDermott 1977) and the “white oaks” probably were a collection of overcup, swamp white, post, and swamp chestnut oak. GLO notes that describe general habitat types of forest, bottomland, prairie, open water, etc. do not describe composition of forests nor do they delineate small areas of trees or herbaceous wetlands within bottomland settings (Bourdo 1956, Hutchinson 1988). GLO surveys probably mapped savannas as forest, but this is unclear because many savanna areas may have contained larger amounts of prairie or other grasses. In the SJNM, GLO notes and maps often mix the terms “bottomland”, “woodland”, and “forest”. Most “bottomland” appears to have been BLH communities, however, the scale of mapping, and definition of communities often is gross and inconsistent. Further, GLO notes suggest travel

through, and precise documentation of, vegetation in low elevation, wet, floodplain locations (such as abandoned channels and floodplain depressions) was difficult and somewhat cursory. Notes in these areas often refer to lands simply as “water”, “wet”, “swampy”, “marais”, or “flooded.”

In addition to the GLO surveys, many other cartographers, naturalists, and explorers produced maps (often small-scale maps of a local area) and provided natural history accounts and botanical records for many southern Middle Mississippi and Upper MAV areas (Hutchins 1784, Brackenridge 1814, Nuttall 1821, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Warren 1869, Allen

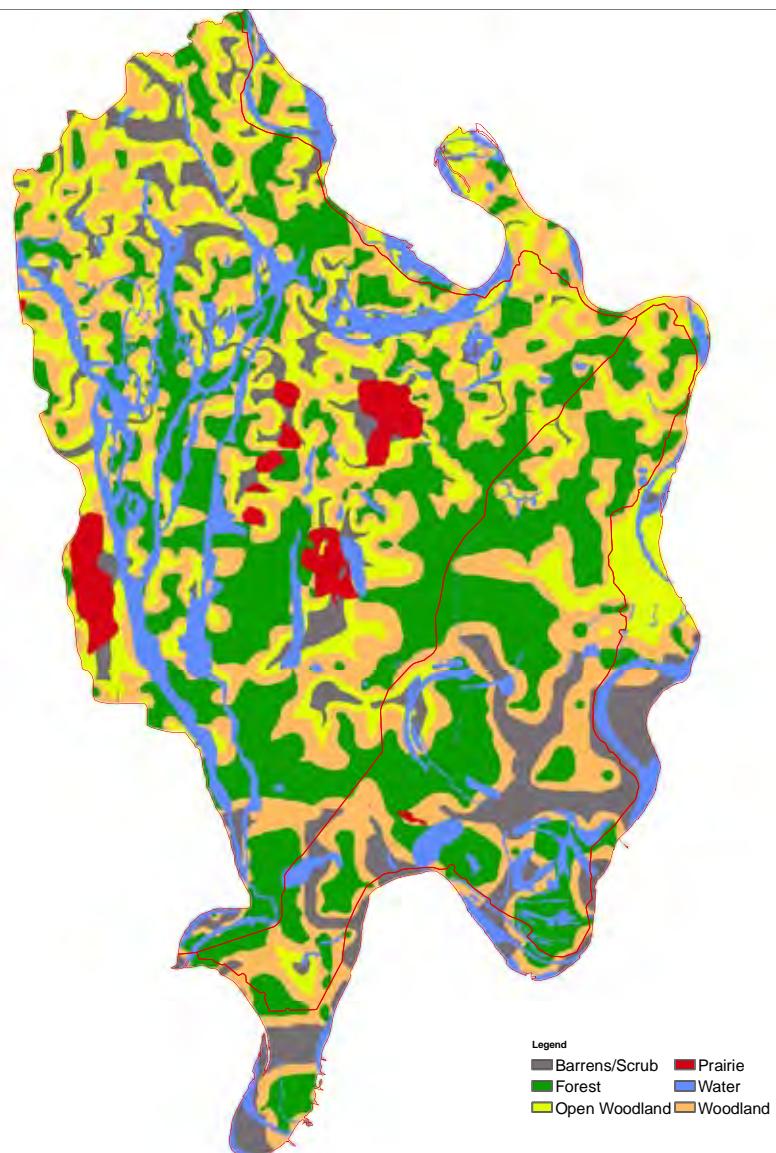


Figure 23. Model of vegetation communities in the SJNM during the early 1800s compiled from General Land Office survey maps (from CARES 2010).

1870, Brink and Co. 1875). In the late 1800s the Mississippi River Commission (MRC, 1881, 1893–1904) produced the first complete set of maps for the Mississippi River from New Orleans to Minneapolis. This map set included detailed descriptions of the Mississippi River channel, side channels and chutes, tributaries, floodplain habitats (general habitat types), floodplain lakes, and settlements (Fig. 24). Other maps from the early 1900s also delineated low elevation “swamp” and “lowland” areas where abandoned channels and floodplain wetland occurred (Fig. 25).

Collectively, the above maps, historical accounts, and published literature suggest historical vegetation communities in the SJNM were distributed along elevation, geomorphology, and hydrological gradients similar to current plant physiographic of the community species. Similar community distribution associations also occur in other nearby Mississippi Valley floodplain areas and help validate information for the SJNM (e.g., Heitmeyer et al. 2006, Heitmeyer 2008, Klimas et al. 2009). The extensively documented relationships between community types and the abiotic attributes of Upper MAV geomorphology, soils, topography, and flood frequency zones were used to prepare Hydrogeomorphic matrices that identified the potential distribution, composition, and area of Presettlement habitats in the SJNM (Table 4). The methods of determining these relationships were presented earlier in the report and involved a series of steps of overlaying data layers from historical and current maps and then validating relationships using remnant representative field reference sites (see Klimas et al. 2005, 2009; Nestler et al. 2010). This methodology culminated in production of a map of potential Presettlement vegetation community distribution in the SJNM (Fig. 26).

In the late 1700s, several Mississippi River side channels, chutes, and bars were present in the SJNM, but their location was constantly changing as the river frequently migrated (e.g., Fig. 20, Brauer et al. 2005). More stable position Bottomland Lake communities historically were present in many abandoned channel areas in the SJNM during the late 1700s. More recent abandoned channels likely contained more open water habitats while older ones filled with alluvial sediment gradually became dominated by bald cypress-water tupelo and Low BLH habitats. All Bottomland lakes have Sharkey and Alligator clay soils and are flooded annually, sometimes for extended periods over several years.

Table 4. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the St. John's Bayou/New Madrid Floodway region in relationship to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared from the Government Land Office survey notes taken in the early 1800s, historic maps prepared by Hutchins in 1784, Collot in the 1790s, de Finiels in the early 1800s, and the Mississippi River Commission in 1890; U.S. Department of Agriculture soil maps, geomorphology maps prepared by Saucier in 1994; flood frequency data provided by the U.S. Army Corps of Engineers, Memphis District; and various naturalist/botanical accounts and literature.

Habitat Type	GeomorphicSoil surface ^a	type ^b	Flood frequency
Bottomland lake	Hchm	Clay	Annual to Permanent
Low BLH	Hchm, Hpm1	Silty-clay	Annual, 4-6 months
Intermediate BLH	Hpm1, PvI1,2, Pvcl	Silty-clay loam	2-3 months, dormant season
High BLH	Hpm1, PvI's, Pvcl	Silt loam	1-2 months, dormant season
Terrace Hardwood	PvI's, Pvcl, Pve, Ps	Sandy loam	> 5 year
Riverfront forest	Hpm1,Bar-and-chute	Sandy loam Loams, fine sand	Annual 1 yr
Savanna	Pve, Ps, PvI1	Loamy sand	> 10 yr
Sand prairie	Pve, PvI1	Fine sandy	> 100 yr loam

^a Pve – Sikeston Ridge, Pvcl – relict channels Valley Train, Ps – interfluvia sand dunes, PvI – undifferentiated Holocene Valley Train braided terrace, PvI1 – Late Holocene Valley Train braided terrace, PvI1 – Early Holocene Valley Train braided terrace, Hpm1 – Holocene Point Bar meander belt, Hchm – abandoned Mississippi River channels.

^b See Appendix B for complete list of soils associated with vegetation communities in various geomorphic surfaces.



Figure 24. An example of a Mississippi River Commission map (1881) prepared for the SJNM.

The numerous abandoned channels in the SJNM caused Bottomland Lake communities to be distributed throughout the region and they historically covered over 20,000 acres (Fig. 3).

Forests covered over 93% of the historic SJNM landscape and were a heterogeneous mix of Riverfront, BLH, and Terrace Hardwood communities (Table 5, Fig. 26). Riverfront Forest historically covered 9.3% of the SJNM and was distributed primarily in a band parallel to the active Mississippi River channel, but it also occurred in limited sites in older abandoned channel locations and along basin tributaries. Most of the current Batture of the Mississippi River was historically Riverfront Forest and occurred on fine sandy loam soils. Low BLH, including Bottomland Lakes, covered 115,419 acres of the SJNM and was present mostly in the Holocene Meander Belt of the Mississippi River (Hpm1), with Sharkey and Alligator clay Vertisol soils, and a one-year flood recurrence regime. Intermediate BLH was widely distributed over 23.8% of the SJNM in the Hpm1 and some valley train relict channels of the Pvcl of the SJNM where flooding occurrence was 1-2 year frequency and soils were silty-clay-loam Mollisols and Inceptisols. High

BLH was present on about 65,000 acres of Hpm1, Pvcl, Pvl1 and Pvl2 surfaces with 2-5 year flood frequencies and mixtures of Mollisol and Entisol silt-loam soils. Terrace Hardwood covered extensive areas (108,755 acres) of higher elevation Ps and Pvl1 surfaces with > 50 year flood recurrence and sandy-loam Entisol soils. Slope Forest was limited on a few small alluvial fan sites adjacent to the Commerce Hills.

Prairie and Savanna historically were distributed on the highest elevations (> 500 year flood recurrence) of the SJNM where loamy fine sand soils were present on braided stream terraces and the Sikeston Ridge. The precise extent of Prairie vs. Savanna in the SJNM during the Presettlement period is unknown. Prairie shown in Fig. 26 includes the Prairie area (13,687 acres) mapped by GLO surveys (GLO 1817-40). Hydrogeomorphic analyses suggested a slightly smaller area of pure Sand Prairie (11,405 acres) but a larger area of Sand Savanna (21,617 acres) that had a strong Prairie component (Table 5). By the time GLO surveys were conducted in the early 1800s, the extent of pure Sand Prairie undoubtedly was greatly reduced and disjunct compared to the Prairie area that probably occurred during maximum Prairie extent period of the Altithermal over 4,000 years BP (Delcourt et al. 1999). The Hydrogeomorphic-derived matrix produced in this study suggests a wider distribution of Prairie or mixed Prairie-Savanna in the mid to late 1700s than the GLO surveys recorded in the early 1800s. By the early 1800s, it also appears that some former Prairie areas had already been converted to agriculture (Schroeder 1981). Notes from the GLO surveys and some older maps suggest the areas surrounding remnant Prairie recorded in the early 1800s was a more open forest landscape often with post oak, blackjack oak, and hickory recorded (see also Schroeder 1981, Hendershott 2004). Consequently, it is likely that much of the high elevation sandy terrace and ridge landscape of the Ps and Pvl1 was Savanna, albeit perhaps in transition to a more complete forest cover by the late 1700s. Given the uncertainty of the exact Prairie and Savanna distribution in the SJNM in the late 1700s, Fig. 26 identifies a fairly large Savanna area that may have included small patches of pure Prairie or relatively open, sparsely treed, Savanna.

Table 5. Area (acres) of major vegetation communities/habitat types present in the St. John's Bayou/New Madrid Floodway region during the Presettlement period predicted by Hydrogeomorphic matrix mapping compared to current conditions.

Community type ^a	Presettlement	Current
Low BLH	115,419	1,400
Intermediate BLH	114,574	700
High BLH	62,070	400
High BLH-Natural Levee	2,879	100
Terrace Hardwood	108,755	250
Riverfront Forest	44,901	1,500
Slope Forest	694	70
Sand Savanna	21,617	50
Sand Prairie (GLO) (Hydrogeomorphic matrix)	13,687 11,405	100



Figure 25. Map of low "swamplands" in southeast Missouri in 1903 (historic base map obtained from Little River Drainage District files, Kent Library, Southeast Missouri University, Cape Girardeau, Missouri; georeferenced/shapefile created).

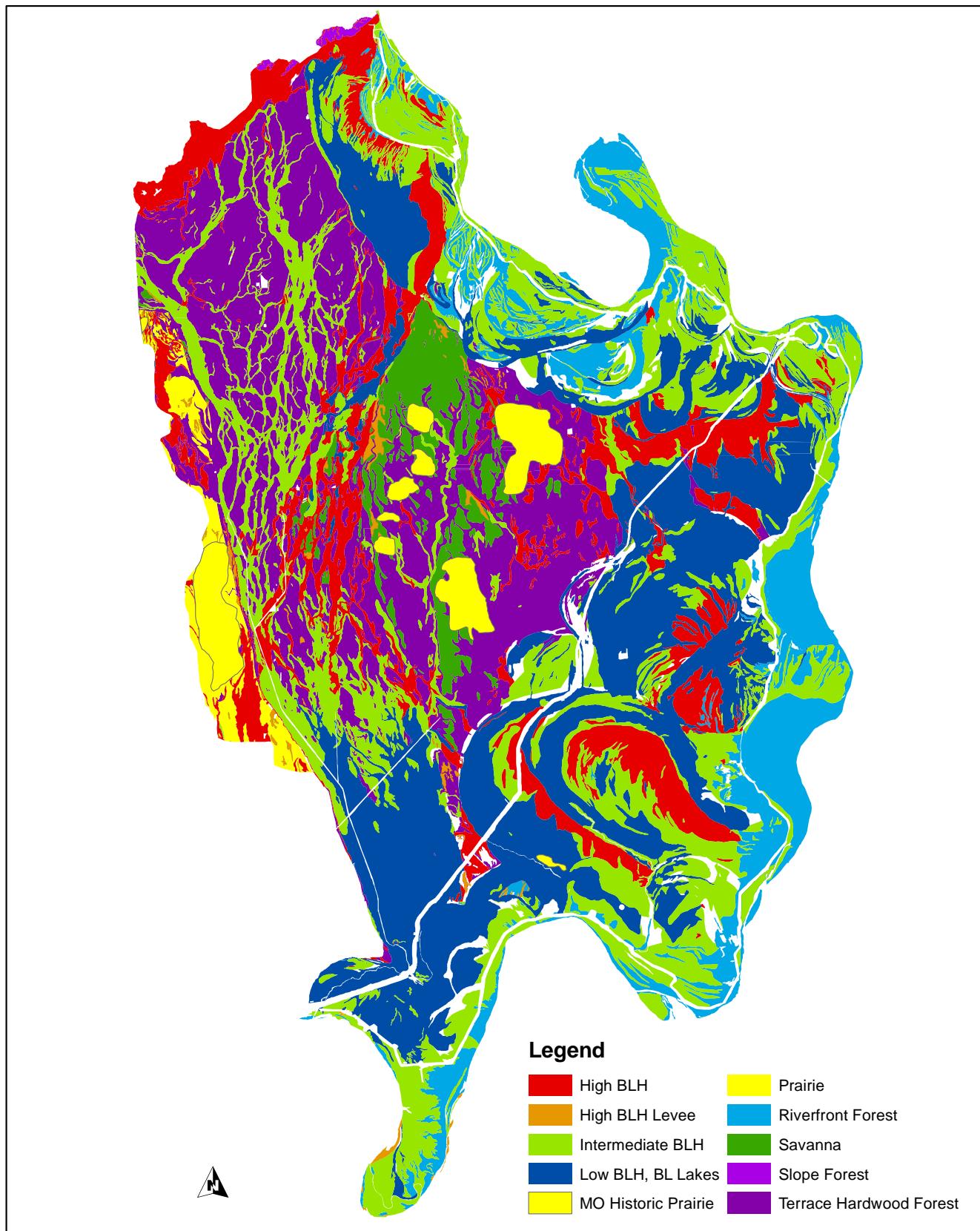


Figure 26. Map of potential distribution and types of vegetation communities in the SJNM.



CHANGES TO THE SJNM ECOSYSTEM

REGIONAL LANDSCAPE CHANGES

Settlement and Early Landscape Changes

The chronology of human occupation in parts of the SJNM is reviewed in Buchner et al. (2009) and several other archeological publications (e.g., Lafferty and Price 1996, Lewis 1996, Lafferty 1998).

A summary of occupations and potential use of, and effects, on natural resources and communities is provided in Fig. 27 and below.

The first evidence of initial permanent occupation of the SJNM by native people is from the Middle Archaic period (Buchner et al. 2009:67) although Paleoindian and Early Archaic peoples undoubtedly traveled through the SJNM prior to that time (Lafferty and Price 1996). Glacial outwash was still being actively deposited in the region prior to the Altithermal period (4,000 to 8,000 years BP) and seasonal movement of people to exploit econiches in the SJNM garnered from a hunter-gather lifeway dominated this era. The advent of the Altithermal apparently caused the region to become warmer and drier and Prairie and Savanna expanded into the higher elevations of the region. At this time native people appear to have congregated at a limited number of higher elevation locations mostly on natural levees near permanent water areas of Bottomland Lakes or river channels. The Late Archaic period (3,000 to 500 years BP) was a time of great expansion of native populations at numerous sites as the climate ameliorated. At this time cultural elaboration caused settlements to become more specialized to exploit certain resources at

specific times of the year and areas became occupied seasonally as populations shifted from dispersed to aggregated settlements. The end of this period also marks the development of horticulture and the introduction of pottery into the SJNM. Many animals were utilized including white-tailed deer, small mammals, migratory birds, fish, and amphibians (Buchner et

AMERICAN ERA		
HISTORIC	A.D. 1803	COLONIAL ERA
PROTOHISTORIC	A.D. 1673	Few scattered sites, none on Barnes Ridge "Megadrought" during 1560s-1590s
	A.D. 1540	Abandonment, the "Vacant Quarter"
MISSISSIPPI	A.D. 1450	Large population in Cairo Lowland Development of towns Maize agriculture Shell-temper & clay-temper ceramics
	A.D. 1000	A tentative phase Mississippian traits introduced (maize, vessel forms) Rise of hierarchical settlement systems Clay-tempered ceramics dominate
COLES CREEK (TERMINAL WOODLAND- EMERGENT MISSISSIPPINIAN)	BECKWITH PHASE	
	A.D. 800	Key site is Hoecake Bow and arrow is introduced Dispersed population, formation of territorial units Clay-tempered ceramics dominate
BAYTOWN (LATE WOODLAND)	HOECAKE PHASE	
	A.D. 400	Local Hopewell expression Burial mound(s) at LaPlant and St Johns? Possible site-unit intrusion from southern Illinois
MARKSVILLE (MIDDLE WOODLAND)	LA PLANT PHASE	
	100 B.C.	
TCHULA (EARLY WOODLAND)	BURKETT PHASE	Similar to O'Bryan Ridge w/ introduction of ceramics Sand-tempered ceramics appear diagnostic Few components identified 14C data suggest this phase is early Middle Woodland
	500 B.C.	
POVERTY POINT (LATE ARCHAIC)	O'BRYAN RIDGE PHASE	First widespread local culture Hallmark is baked clay objects (BCOs) Both large sites w/ deep middens & small sites occur Evidence for chenopod cultivation at 23MI605
	3,000 B.C.	
MIDDLE ARCHAIC 4,000 B.C.	LATE	Colonization by bands using Hickory-Ridge points
	5,000 B.C.	Hypsithermal (7000-3000 B.C.) has major impact ca. 5500-3500 B.C.
EARLY ARCHAIC		No evidence for occupation ca. 8000-4000 B.C.
	7,900 B.C.	
PALEOINDIAN	DALTON	
	8,500 B.C.	Barnes Ridge laid down ca. 9000-8000 B.C.
	CLOVIS	
	10,000 B.C.	

Figure 27. Cultural chronology of the SJNM (from Buchner et al. 2009).

al. 2009). Ridge locations were usually chosen for camps and settlements because surrounding floodplain areas were seasonally inundated and contained dense swamp-type vegetation. Evidence suggests that people were highly mobile hunter-gathers well adapted to seasonal floodplain resource availability through the Late Archaic period and likely had little effect on vegetation community distribution or disturbances (Lafferty and Price 1996).

During the Woodland period, horticulture intensified on the higher ridges of the SJNM and other developments included construction of earthworks, reorganization of social structure, and elaboration of artistic expression and burial rituals (Griffin 1967). The Early Woodland period (2,100 to 2,500 years BP) marked initial use of ceramics and some expansion of horticulture including more expansive maize production in the SJNM. By the Middle Woodland time, burial ceremonialism and artistic expression were elaborated and “mound” construction apparently occurred in some more permanently settled areas. By the Late Woodland period (1,600 to 1,200 years BP) many cultural shifts began occurring including substructure mound-and-plaza complexes, two-tiered social hierarchy, formation of territorial units, increased reliance of maize production, new technologies such as the bow and arrow, and tempered ceramics. The Lilbourn and Towosahgy sites were two of the largest civic ceremonial locations during the Late Woodland and Early Mississippian periods (Lafferty and Price 1996). It is possible that this time period represented the maximum prehistory occupation of the SJNM by native people and that some areas on higher ridges, natural levees, and Valley Train terraces were converted to agriculture and settlements with regular disturbance of surrounding habitats using fire and perhaps limited clearing (Buchner et al. 2009).

During the Mississippian period the final climax of native cultural development occurred in the SJNM region and it is possible that the region supported one of the largest populations in the southeast U.S., not far behind the huge population center at Cahokia (Phillips 1970). At this time populations expanded in the region, intense settlements occurred on high ridges in the floodplain, more emphasis was placed on agricultural production, earthworks were constructed based on celestial alignments, inter-regional exchange of items occurred, shell-tempered ceramics were made, and some regional warfare was present to protect territories (Buchner et al. 2009). These developments led to the conscripted, complex socio-

political system known as chiefdoms (e.g., Milner 1998). Undoubtedly larger occupation sites caused anthropogenic effects on local ecosystems and plant communities including more widespread clearing and maintenance of agricultural fields and local high exploitation of fish and wildlife populations. A general abandonment of the Mississippian ceremonial centers and villages in the SJNM occurred after 1550. While the region may not have been completely vacant, it appears populations dispersed and relocated.

The Protohistory period 1540-1673 is generally considered to have the first appearance of Europeans in the southeastern U.S. De Soto visited several chiefdoms in the St. Francis Basin in 1541 but when Marquette and Joliet descended the Mississippi in 1673, no natives were encountered in the SJNM project area (Marquette 1954). They did encounter Quapaw settlements on the west bank of the Mississippi River upstream of its confluence with the Arkansas River. Historians believe the Quapaw had migrated through the SJNM area from their Ohio River homeland earlier in the 17th century. A few scattered households, possibly villages, of Native Americans lived near the Mississippi River for at least 50 miles south of Cairo

Including the SJNM (Buchner et al. 2009:91), but general abandonment of the region existed perhaps partly because of increasing pressure of Iroquois raids beginning about 1650. During the Early Historic Period the SJNM probably was claimed as hunting ground by the Illini, Shawnee, Osage, Quapaw, and Michigamea (Satz 1998). As the SJNM became unoccupied, former agriculture fields and settlement sites likely regenerated back to forest communities and vegetation species composition probably graded from early succession or disturbance-type species early on to more complex floodplain/BHL communities thereafter (King et al. 2005).

Southeast Missouri was part of Louisiana (New France) during most of the Colonial Period 1673 to 1803. In 1756 the Seven Years' (French and Indian) War broke out as France sought to fortify the Ohio Valley. Prior to France's defeat by the British and their allies in 1763, France secretly ceded Louisiana to the Spanish, and although the region was subsequently returned to France in 1800, many Spanish officials still held office until 1803. French settlements were typically clustered along the Mississippi River, but locations often were moved or destroyed (e.g. early New Madrid) as the river migrated. Most Colonial settlements were founded on fur trade; the

bend of the river where New Madrid currently is located was known as L'Anse a la Graiss, meaning a cove of “fat” (Houck 1908) or greasy bend, where Indian hunting camps were located and bear and buffalo grease was boiled down (Foley 1989).

In 1783, two French Canadians, Francois and Joseph Le Sieur lived at L'Anse a la Graiss for a season and recommended establishment of a trading post there. The site offered high ground (natural levee) along the Mississippi River and a settlement became established soon thereafter. In 1789, Colonel George Morgan, an American, attempted to create a town at the location by obtaining a vast land grant – known as New Madrid – that could serve as a buffer between English colonists and Mexico. However, the Spanish Governor in New Orleans only offered a ca. 1,000 acre tract and Morgan abandoned his city plans, but the proposed name of New Madrid stuck and replaced L'Anse a la Graiss. The Spanish constructed a fort at New Madrid in 1789 and the city served as a Spanish port of entry until it was surrendered to American authorities in 1804 following the Louisiana Purchase.

During the late 1790s, Anglo-American settlement increased in the SJNM region and Spanish Land Grants were given generously to local citizens for settlement and farming. Many of these initial land grants were made on higher “prairie” or “savanna” ridges especially on Sikeston Ridge (Buchner et al. 2009). Other land grants usually were on higher ridge locations and some clearing of forest in these sites began to occur at this time (Douglass 1912). Combined mills and travel corridors were built to transport people, agricultural crops, and goods during this time (Houck 1908, Ogilvie 1967) – interestingly, some sites were destroyed as floods and further Mississippi River migrations occurred (e.g., Fisk 1944). By 1795, the Spanish government concluded that further attempts to develop Louisiana into a buffer from Anglo-American penetration were not possible and it became a bargaining chip in international diplomatic relations and was returned to France.

The Colonial Period ended with the Louisiana Purchase in 1803. Missouri was part of the Louisiana District and Territory until 1812 when the Missouri Territory was formed. The large New Madrid earthquakes of 1811-12 heavily damaged the town of New Madrid and discouraged additional settlement in the region for many years. After the War of 1812, Anglo-American immigration west in the U.S. increased rapidly and steamboat travel and commerce on the Mississippi River accelerated (Brauer et al. 2005,

Buchner et al. 2009). Many new settlements were established along the Mississippi River between the Ohio River and New Madrid in the early 1800s, but major development of the area did not occur until the mid 1800s. Historic tribes affiliated with the project area in the late 18th century included the Shawnee, Delaware, and Muscogee Creek. According to the historian Morrow, the site of the present day New Madrid was originally a large Delaware town. During the Trail of Tears episode in the 1830's the Cherokee and Creek Indians also moved through the project area.

Early Missouri Statehood and Development of the SJNM

Missouri was granted statehood in 1821 and at that time the population of New Madrid County (created in 1812) contained about 2,200 people but the county at the time included most of what is now Scott, Stoddard, Mississippi, Dunklin, and Pemiscot counties. The very sparse population of the SJNM region and its flood prone landscape prohibited much development, and conversion of native plant communities, except on the highest elevation ridges and natural levee locations during the early 1800s. The town of New Madrid did not recover from the earthquake until about 1822 when the county seat was permanently located there; the town was reincorporated in 1834. Development of New Madrid and other regional Mississippi River settlements was stimulated by commerce from steamboat traffic in the 1840s and 1850s. Increasing steamboat traffic fostered new settlements and clearing of forest areas along the river. These settlements often began as wood yards to supply steamboats with fuel and then later became farms, plantations, communities, or landings (Powell 1975). In Mississippi County the first towns of Norfolk and Rush Ridge were established and Wolf Island also became established by Kentuckians and Virginians. St. James was established prior to 1859 at the mouth of James Bayou and supported two sawmills. Much of the timber cut for steamboats was Riverfront and BLH Forest species on natural levee surfaces that were easily accessed and delivered to the river ports.

Starting in the mid 1810s and continuing to the 1840s, the GLO surveyors subdivided the SJNM into townships and sections and prepared the first detailed georectified maps of the area. Given that only sparse human populations were present at this time, it seems likely that the GLO notes and maps represent a mostly unmodified landscape condition

and reflects natural ecological processes operating in the region except on higher ridges and natural levees (see previous discussion of Prairie and Savanna distribution). The GLO surveys seldom found farm clearing > 40 acres in wooded areas, but in contrast did find larger fields and developments on more open lands where Prairie and Savanna had existed on Sikeston Ridge and Valley Train terraces north and west of the current town of East Prairie.

Large numbers of settlers began occupying the SJNM during the 1840s and 1850s; for example, 28 land patents were issued for a four-square mile area near Barnes Ridge during 1848-59 (Buchner et al. 2009:96). Most early settlement was on ridges or more open areas and corn was the dominant crop grown (Table 6). By the early 1900s, more extensive areas of the region were farmed and diversified crops were grown (Table 6). Livestock production also accelerated in the area during the late 1800s. Coincident with increasing settlement and agricultural production was construction of railroads (Willis 1933). The St. Louis and Iron Mountain Railroad was chartered in 1851 and the Cairo and Fulton Railroad was chartered in 1853. Charleston, established in 1860, became the meeting place for these two railroads and spur lines were distributed to many settlements such as Birds Point by the 1860s. By the time of the Civil War, the Cairo and Fulton Railroad extended to Poplar Bluff, Missouri. The city of Hibbard, later

renamed East Prairie, was founded in 1883 by the St. Louis Southwestern Railway Company (www.eastprairiemo.net).

After the Louisiana Purchase, all lands in southeast Missouri became public domain, but land sales did not begin until 1818 and the earlier Spanish Land Grants created difficulty and controversy in dividing landscapes. Boundaries and legal standing of some Spanish Land Grants remain uncertain even today. Initially, public land was sold in 640 acre tracts but political and economic conditions eventually allowed minimum land purchase of 80+ acres. Later the Homestead Act of 1862 required a homesteader to settle on and cultivate up to a 160-acre tract for five years to obtain title. The Civil War in the 1860s created unrest in the SJNM and deterred additional settlement and clearing of forest areas or agricultural/commercial development. In 1869, Missouri passed "An Act in Relation to Swamp and Overflowed Lands within the limits of several counties." This act conveyed all un-patented "swampland" to the counties they were located in. Following the Civil War, "tenant" farming began to decentralize the old plantation system of the mid-southern U.S. including some larger plantation land holdings in the SJNM. This tenant period lasted from the 1870s to about 1950 and many small farms were established throughout the area. The small farms, coupled with land reclamation and drainage projects (see below) gradually fragmented and cleared much of the forest in the

SJNM (Korte and Fredrickson 1977, MacDonald et al. 1979).

Following the Civil War technological changes shifted from steamboats to railroads and caused important shifts in commerce and mass production of consumer goods in the southern U.S. (Houck 1908). Repairs to rail lines damaged in the war and additional line expansion eventually connected larger communities in southeast Missouri and many lines, usually located on ridges or higher elevation terraces began to cross the SJNM. Increased transportation capabilities also stimulated clearing of floodplain forests and conversion of native communities to more extensive agricultural production. Coincident with the expansion of agricultural lands were efforts to drain low-lying areas.

The development and conversion of much of the SJNM to agricultural land in

Table 6. Historic statistics for various agricultural crops produced in Mississippi and New Madrid counties, Missouri (from Buchner et al. 2009)

New Madrid County	Corn (bu.)	Wheat (bu.)	Cotton (bales)	Tobacco (#)
Census Year				
1840	461,110	9,503	2†	0
1850	586,260	195	0	0
1860	802,306	20,243	0	2,400
1870	No data			
1880	1,116,696	49,273	1,649	14,243
1890	886,158	74,909	1,505	3,450
1900	1,247,050	268,010	1,602	400
1910	2,091,907	202,941	5,600	150
1920	1,476,894	736,110	7,192	—
Mississippi County				
Census Year	Corn (bu.)	Wheat (bu.)	Cotton (bales)	Tobacco (#)
1850	354,700	3,727	0	0
1860	543,095	30,074	0	0
1870	491,990	5,225	57	6,160
1880	1,509,055	110,448	132	21,010
1890	1,304,686	167,498	17	16,960
1900	1,358,380	230,040	11	340
1910	2,230,545	595,943	74	0
1920	1,054,561	733,009	298	0

† in 1840 cotton production was reported in pounds

The 1840 data are not available for Mississippi County as it was not formed until 1845.

the late 1800s and early 1900s was closely linked with flood control and drainage projects (Douglass 1904, Korte and Fredrickson 1977, Fredrickson 2005). The Swamp Act of 1850 gave Missouri 3.3 million acres of overflow land, primarily in southeast Missouri. The Act provided that proceeds from the sale of the lands would be used to construct an eventual extensive network of levees and drainage ditches (Fig. 28). Mississippi and New Madrid counties were major beneficiaries of the Act and after a major flood in 1858; work began on the construction of a levee along the Mississippi River 30 miles south of Birds Point. Its height was equal to the 1815 flood which Abraham Bird had recorded by cutting a mark on a tree. Most levee and ditch building was uncoordinated private efforts until the late 1890s, when numerous drainage districts were established by taxing land owners in the district area. One large drainage district was the St. John Levee and Drainage District that, for example assessed drainage district taxes of \$0.15/acre. These early drainage districts and their projects began to substantially modify flood duration and extent in the SJNM and contributed to early conversion of historic habitats to farmland (Korte and Fredrickson 1977).

A large flood occurred over much of the MAV in 1927 and led to Congressional passage of the Flood Control Act of 1928, which authorized the Mississippi River and Tributaries Project including works in the SJNM (Barry 1998, USACE 2009a). The Act projects included: 1) construction of levees and floodwalls to contain floods, 2) floodways to pass excess flows past critical Mississippi River reaches, 3) channel improvements and stabilization to improve efficient navigation, and 4) tributary basin improvements. Levees along the Mississippi River in the SJNM were

expanded, raised, and constructed starting with the New Madrid-Sikeston Ridge Levee (Fig. 2) in 1928. A second large flood control project following the Flood Control Act of 1928, known as the "Jadwin Plan" after Edgar Jadwin that presented the idea to Congress, was construction of the Birds Point - New Madrid Floodway. This Floodway was designed to lower flood stages upstream and adjacent to the Floodway during major flood events. Initial construction of the Floodway began in 1929 and was completed in 1933. It included a 130,000 acre flowage right from Birds Point to New Madrid and constructed a frontline "fuseplug" levee along the Mississippi River constructed at a height equivalent to a 57 foot Mississippi River stage at the Cairo gauge. On

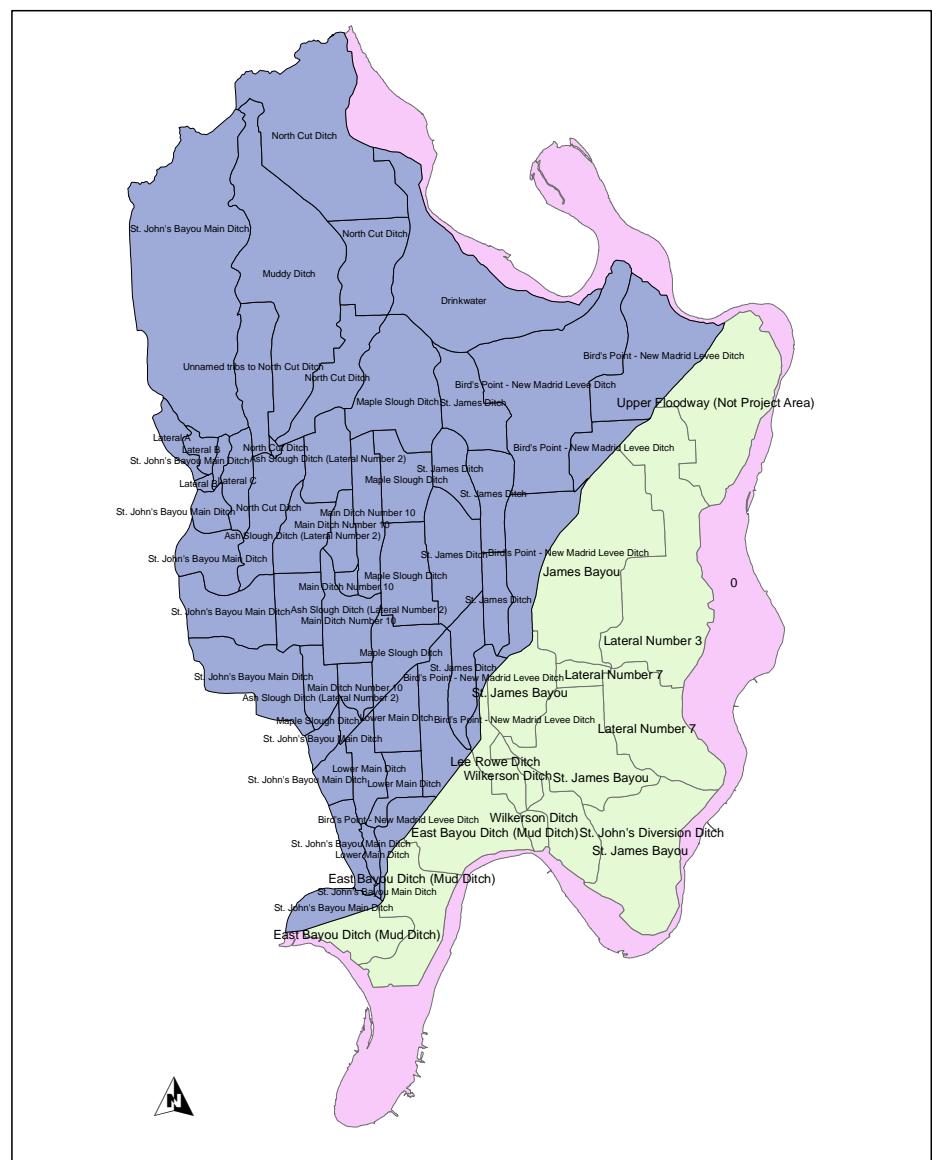


Figure 28. Major ditches in the SJNM.

the backside of the Floodway, a higher levee equivalent to a 60 foot Mississippi River stage at Cairo was constructed to protect lands to the west of the Floodway. In case of a great flood, the fuse-plug levee was designed to blow out – or it can be artificially breached (i.e., it was dynamited in 1937). The New Madrid Floodway diverts a maximum flow of 550,000 cfs (Barry 1998). At the southern end of the Floodway, the frontline and setback levees were not joined, leaving a gap of about 1,500 feet. The purpose of the gap was to provide drainage to the New Madrid Floodway via Mud Ditch. While the gap was provided as a drainage outlet, it by default also allows Mississippi River backwater to inundate the lower Floodway. Similarly, a 4,200-foot gap was left in the levee separating the New-Madrid-Sikeston and Birds Point-New Madrid levees to provide an outlet for the St. John's Bayou Basin and while it provided a flow outlet, it also allowed Mississippi River backwater to inundate the lower part of the St. John's Basin.

Another large flood occurred in the Upper MAV in January 1937 and all previous flood stage records were or would soon be broken. In an attempt to save Cairo from massive flood devastation, the fuse-plug New Madrid Floodway was breached with explosives and the Floodway lands were quickly inundated with subsequent large livestock and property losses. Relict braided stream and abandoned channels were flooded and acted as conduits for flood flows, perhaps similarly to how they transferred water during Holocene glacial outwash events.

Political fallout from the 1937 Flood eventually led to the Flood Control Act of 1946, which

authorized the closure of the 4,200 foot gap in the southern St. John's Bayou Basin. A levee was constructed across the gap and six 10 x 10 feet reinforced concrete culverts built with power-operated lift gages at the outlet end were constructed across St. John's Bayou (Fig. 29). Construction was completed in 1953.

The subsequent Flood Control Act of 1954 amended the Bird's Point – New Madrid Floodway Project by authorizing modifications to the Floodway in accordance with U.S. House of Representatives Document 132, 83rd Congress. This document recommended construction of a new levee extending about 1,800 feet from the fuseplug section of the frontline levee across the existing New Madrid Floodway gap to the setback levee and the construction of a floodgate for release of interior drainage. Construction of the levee was deferred until a pumping station was authorized. Further modification to the floodway was authorized by the Flood Control Act of 1965, which recommended “raising the levees forming the east boundary of the Birds Point – New Madrid Floodway and modifying operation to include breaching of the fuseplug levee during floods that reach 58 feet and threaten to exceed 60 feet at Cairo. Whereas the plan authorized by the 1928 Flood Control Act provided for operation of the Floodway by overtopping a fuse plug levee when the Mississippi River reached 55 feet at Cairo, the 1965 Act provided for artificial breaching of the levee at 58-60 foot level. As a result of the modified plan for operation, modified flowage easements were purchased on lands > 300 feet elevation NGVD. Finally, in 1986, the Water Resources Development Act authorized channel modification and pumping stations for the St. John's Bayou Basin and the New Madrid Floodway, which currently are being evaluated with a plan formulation for the region (USACE 2009b).

Vegetation Community Changes from the late 1700s to the Present

Current land cover in the SJNM is dominated by agricultural cropland except in the Batture land region (Fig. 30, Tables 5, 7). Essentially all historic Prairie and Savanna are gone, and total forest area is only 6% and 7.8% of total area in the St. John's Bayou Basin and New Madrid Floodway, respectively. Comparison of historic forest communities (Fig. 26) with contemporary aerial



Figure 29. Photograph of the floodgate structure at the south end of St. John's Bayou Basin.

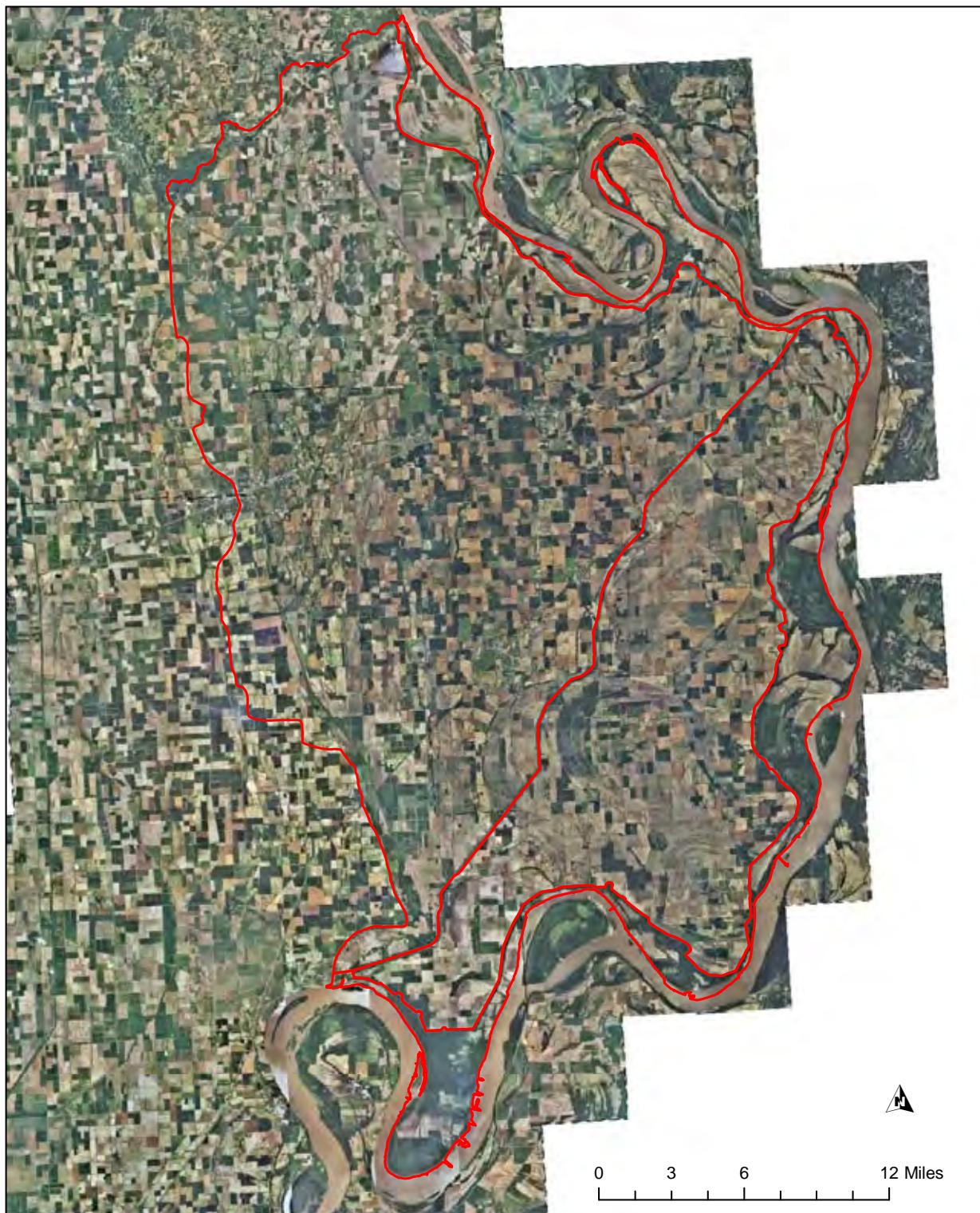


Figure 30. 2009 NAIP photograph of the SJNM identifying remnant forest communities.

photographs (Fig. 30) that show remnant forest tracts identifies that remaining tracts are primarily Riverfront Forest communities with small tracts of BLH scattered in the region. The only large forest tracts in the SJNM are scattered Riverfront Forest

tracts in the Batture land and Floodplain and BLH forests at Donaldson Point, Big Oak Tree, and the Bogle Woods adjacent to Ten Mile Pond CA. These larger tracts now are all in public ownership. Mean area of remnant forest tracts in the SJNM is < 20



Figure 31. Photograph of small remnant High BLH forest tracts in the St. John's Bayou Basin.

ha, and when the larger tracts listed above are excluded, the mean area of forest tracts is < 5 ha (Fig. 31, Twedt and Loesch 1999). Less than 10

plain and BLH communities remained (Table 8). Forest loss continued to mount during the 1950s, 1960s and 1970s, and by 1974 < 3% of Presettlement

Table 7. Current land cover acres in the St. John's Bayou Basin and New Madrid Floodway (from USACE 2009a).

St. Johns Bayou Basin Total Landcover			New Madrid Floodway Total Landcover		
Land Use	Total Acres	Percent Landcover	Land Use	Total Acres	Percent Landcover
Forested	20,096	6%	Forested	10,368.7	7.8%
Scrub-shrub/Marsh	269.6	0.1%	Scrub-shrub/Marsh	878.2	0.7%
Cropland	280,289.8	86.5%	Cropland	113,007.3	85.2%
Pasture	1,277.4	0.3%	Pasture	922.2	0.7%
Herbaceous	21,121.0	6.5%	Herbaceous	6,624.7	5%
Open Water	944.2	0.3%	Open Water	797.3	0.6%
Sandbar	166.5	0.1%	Sandbar	6.6	0%
Urban	8.1	0%	Urban	0	0%
TOTAL	324,172.8	100%	Total	132,605.1	100%

Project Batture lands		
Land Use	Total Acres	Percent Landcover
Forested	23,796	50.6
Scrub-shrub/Marsh	1,083	2.3
Cropland	18,816	40.0
Pasture/Herbaceous	14	0.0
Open Water	2,123	4.5
Sandbar	1,027	2.2
Urban	188	0.4
TOTAL	47,047	100

four-square mile units of land in the SJNM contain > 15% forest cover (Papon 2002, Warwick 2003).

Most Prairie and Savanna was converted to agricultural land by the late 1800s (e.g., The Mississippi River Commission maps of 1881). In contrast, extensive clearing of forest communities did not occur until the early 1900s (Korte and Fredrickson 1977). Most clearing of forests in the SJNM began on higher elevation ridges, natural levees, and braided stream terraces, but some lower elevation forests were partly cut in the early 1900s for railroad ties and barrel staves (Stanard 1993). Considerable clearing of forest area in Scott, Mississippi and New Madrid counties occurred from about 1910 to 1930 and by 1937 < 30% of Presettlement forests, especially Flood-

Table 8. Chronology of loss of forest in Mississippi and New Madrid counties, Missouri (adapted from Korte and Fredrickson 1977).

County	1937	1947	1957	1967	1974	Total area ^b
Scott	-	-	14,100	7,700	2,800	217,100
Mississippi	82,000	59,000	36,300	20,000	9,600	277,700
New Madrid	99,000	74,000	49,100	25,100	10,100	446,100

^a Includes Riverfront, Bottomland Hardwood, and Terrace Hardwood forest areas.

^b Potential total forest area in the county.

forest area remained in these counties (Table 9). Apparently, slightly slower and less forest conversion occurred in the SJNM compared to non-SJNM areas of these counties, but nonetheless, more than 90% of non-batture SJNM forest lands were cleared by 1980. Most remnant forest communities in the St. John's Bayou Basin and New Madrid Floodway are primarily at elevations 289-298 feet NGVD where flooding is not so prolonged ($> 2\text{-}5$ year flood recurrence interval) as to cause mortality (Table 8). Ironically, however, these higher elevations where High BLH and Terrace Hardwood Forest are most adapted are also the sites where $> 99\%$ forest conversion to agricultural has occurred (Table 5). Remnant forest in Batture

lands are almost all Riverfront Forest communities and at > 290 feet NGVD (Table 9).

About 4,000 acres of Bottomland Lake habitats remain in non-batture lands the SJNM (Table 5). The largest sites are at the Robert G. Delaney and Ten Mile Pond CA's and in other scattered abandoned channel locations. A few, very small tracts of Low BLH also remain in relict valley train channels, along ditches, and other depressions. Non-forested or non-cropland habitats in the Batture are mainly S/S and Open Water habitats along river chutes, sloughs, and side channels.



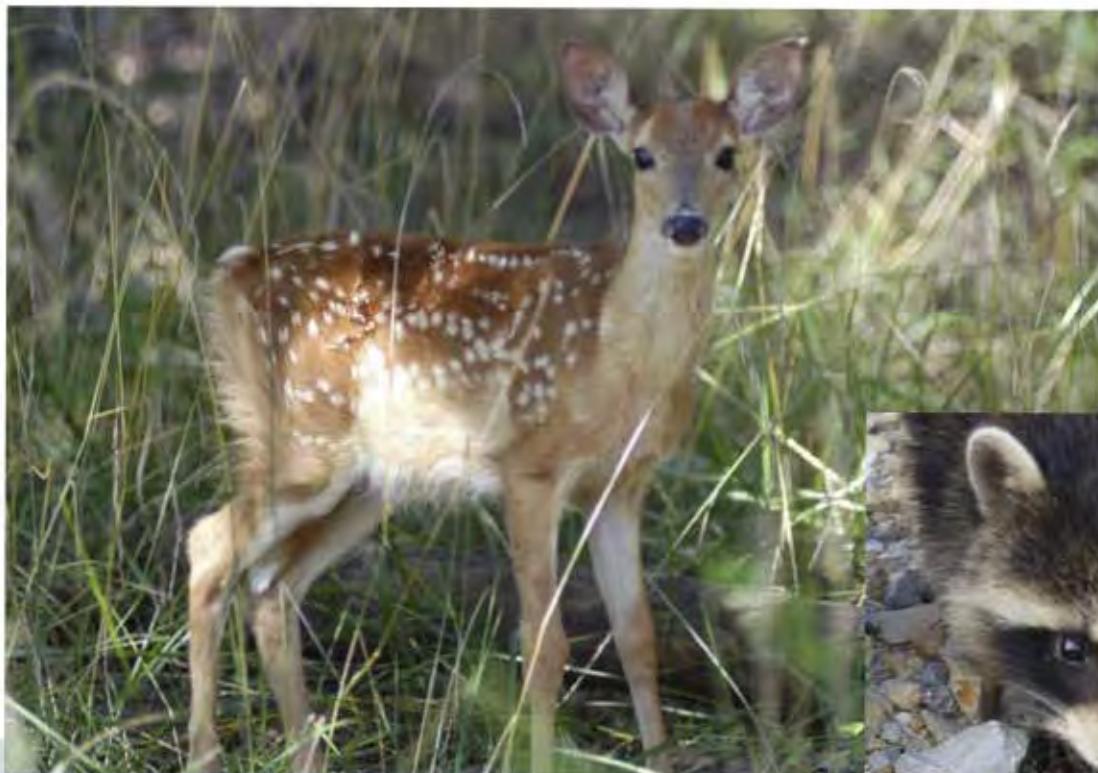
Figure 9. Land cover- habitat type areas in Batture, St. John's Bayou Basin, and New Madrid Floodway regions of the SJNM (from USACE 2009a).

Elevation Feet (NGVD)	Cropland	Fallow	BLH	Large Waterbody	Small Waterbody
281 and below	12	343	255	636	0
282 and below	22	382	338	740	0
283 and below	37	429	424	820	0
284 and below	68	472	557	900	0
285 and below	131	527	724	967	1
286 and below	235	594	999	1,063	7
287 and below	361	658	1,340	1,131	9
288 and below	496	719	1,816	1,246	11
289 and below	687	765	2,464	1,311	13
290 and below	924	810	3,261	1,375	17
291 and below	1,253	855	4,131	1,445	20
292 and below	1,748	905	5,090	1,595	22
293 and below	2,243	955	6,005	1,637	23
294 and below	2,747	1,014	6,956	1,658	24
295 and below	3,291	1,079	7,966	1,679	25
296 and below	3,872	1,170	9,098	1,730	26
297 and below	4,542	1,267	10,324	1,803	26
298 and below	5,303	1,375	11,460	1,876	27
299 and below	5,959	1,475	12,450	1,900	27
300 and below	6,478	1,573	13,332	1,913	27
301 and below	6,895	1,659	14,193	1,927	27
302 and below	7,327	1,726	15,069	1,944	27
303 and below	7,931	1,795	15,957	1,972	27
304 and below	8,645	1,870	16,894	2,001	27
305 and below	9,685	1,933	17,873	2,024	27
306 and below	11,141	1,994	18,837	2,044	27
307 and below	12,803	2,047	19,772	2,060	27
308 and below	14,271	2,089	20,602	2,080	27
309 and below	15,356	2,122	21,262	2,104	27
310 and below	16,044	2,153	21,824	2,110	27
311 and below	16,611	2,186	22,322	2,114	27
312 and below	17,249	2,203	22,765	2,118	27
313 and below	17,773	2,218	23,125	2,120	27
314 and below	18,145	2,236	23,400	2,122	27
315 and below	18,392	2,251	23,571	2,123	27
316 and below	18,543	2,263	23,660	2,123	27
317 and below	18,684	2,270	23,711	2,123	27
318 and below	18,767	2,275	23,748	2,123	27
319 and below	18,800	2,281	23,775	2,123	27
320 and below	18,816	2,285	23,796	2,123	27

Figure 9. Land cover- habitat type areas, (cont'd.)

Elevation Feet (NGVD)	Cropland	Fallow	BLH	Large Waterbody	Small Waterbody
281 and below	229	53	258	39	93
282 and below	310	64	306	45	101
283 and below	398	78	352	48	110
284 and below	494	92	400	50	118
285 and below	1,811	247	811	113	250
286 and below	2,143	317	1,086	120	305
287 and below	2,597	362	1,320	122	322
288 and below	3,056	416	1,556	123	340
289 and below	3,570	481	1,778	125	353
290 and below	6,067	693	2,464	144	486
291 and below	7,413	834	2,676	155	526
292 and below	8,764	910	2,807	163	540
293 and below	10,942	991	2,946	168	552
294 and below	13,401	1,143	3,089	203	566
295 and below	23,389	1,941	3,797	267	639
296 and below	26,851	2,255	4,107	269	673
297 and below	29,092	2,488	4,374	272	697
298 and below	31,700	2,746	4,648	273	707
299 and below	34,562	3,073	4,872	273	714
300 and below	44,546	3,960	5,478	274	741





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CONCLUSION

The Hydrogeomorphic-matrix methodology used in this report provided an objective, science and history-based way, to map potential Presettlement land cover/vegetation community distribution in the SJNM. The SJNM region contained diverse and dynamic hydrogeomorphic attributes that ultimately created landscapes capable of supporting many communities. The specific attributes of geomorphic surface, soil taxonomy, and hydrology are strongly correlated with the distribution and type of communities and each habitat has unique distinguishing characteristics. Prairie and Savanna were historically present on nearly 34,000 acres of Sikeston Ridge, Ps surfaces on the older Valley Train drainage complex adjacent to Sikeston Ridge, and areas > 500-year floodplain on the Charleston Fan (Fig. 26). By the mid to late 1700s, the area of Prairie and Savanna may have been steadily declining from maxima during the Altithermal period ca. 4,000 to 8,000 BP because of wetter, milder, climatic conditions in recent periods. Nonetheless, these sand-based Prairie-Savanna complexes represented important communities an eoniches in the SJNM during Presettlement periods. The higher elevation sand ridge and dune sites were among the first sites to be settled and converted to agricultural croplands by Europeans and most of these habitats were destroyed by the mid to late 1800s. Almost no remnant Sand Prairie or Savanna remains in the SJNM today (Table 5).

Diverse forest communities covered > 93% of the SJNM during the Presettlement period and contained a gradient of Riverfront, BLH, and Terrace Hardwood communities. A small area of Slope Forest also was present on alluvial fans along the Commerce Hills in the far north part of the SJNM. Riverfront Forest was estimated to have covered > 62,000 acres of newly scoured and deposited

bar-and-chute (Woerner et al. 2003, Saucier 1994) surfaces along the Mississippi River channel. The active migration of Mississippi River channels in the SJNM during the Holocene period following erosion of the main channel through Thebes Gap about 10,000 BP has continued to provide suitable geomorphic and soil surfaces for Riverfront Forest and it has been destroyed at lesser percentages than other SJNM historic habitats (Table 5). Much of the remainder of Riverfront Forest, however, is within the Batture lands.

BLH was present on nearly 300,000 acres of the Presettlement SJNM and included Low to High BLH species composition depending mainly on soil and flooding occurrence in the Hpm1 and edges of Pvl, Pvl1, and Pvl2 geomorphic surfaces (Fig. 26). Only a few remnant patches of BLH remain in the SJNM (Table 5) and most are in public-owned or WRP easement conservation lands. In addition to clearing of most BLH for agriculture, the many hydrological alterations to the region from the St. John's Bayou Basin and New Madrid Floodway infrastructure also may have altered the ability of specific sites to support specific BLH communities, if they can at all. For example, the levees and gaps in the region may have shifted hydrological regimes in spring to wetter regimes caused for example, by closure of floodgates in the St. John's Bayou Basin that causes water to inundate areas for longer periods in spring and summer.

Terrace Hardwood forests also were present in extensive areas of higher elevations on Ps, Pvl, Pvl1, and Pvl2 geomorphic surfaces (Fig. 26). Their distribution was primarily determined by the presence of sandy-loam ridge soils that were rarely flooded from high stages of the Mississippi River, but that did receive soil saturation and some ponding in most springs from local precipitation and stream flow.

As with Prairies and Savanna on higher elevations in the SJNM, almost no Terrace Hardwood forests remain in the SJNM.

Bottomland Lake habitats historically were extensive in the SJNM and covered > 20,000 acres of abandoned Mississippi River channels (Fig. 26). Communities in Bottomland Lakes undoubtedly varied over time as the abandoned channels gradually filled and became plugged with alluvial sediments deposited during almost annual backwater flood events from the Mississippi River. New abandoned channels likely contained extensive open water and S/S communities while older ones became Low BLH habitats with open, and annually flooded, bald cypress and water tupelo-dominated canopies. Further, long term fluctuations in wetness and occurrence and extent of seasonal flooding in Bottomland Lakes likely caused at least some seasonal drying of lake margins where emergent and herbaceous wetland plants germinated and provided resources to many animals. In wet years less edge-type herbaceous vegetation was present than in dry years when perhaps large areas of the margins of the lakes dried and supported herbaceous communities.

River chutes, side channels, and bars also were present in the SJNM immediately adjacent to, or in the Mississippi River channel. The distribution and extent of these habitats was undoubtedly very dynamic as the active river channel migrations occurred in the region (Brauer et al. 2005). Conse-

quently, it is somewhat difficult to estimate the precise area of these habitats in the late 1700s, but generally probably at least 10,000 acres of these habitats was present at any given time.

The development of potential Presettlement vegetation community maps provides the foundation for understanding the SJNM ecosystem both past and present. These Hydrogeomorphic-derived maps provide a basis for determining which communities belong in specific geomorphic, soil, and hydrological settings in the SJNM and how contemporary alterations may, or may not, allow these communities to be restored in historic locations if that is desired (Heitmeyer 2008, Klimas et al. 2009). The Hydrogeomorphic analyses also identify the fundamental driving ecological processes that must be present if restoration of specific communities is attempted. For example, restoration of Sand Prairie and Sand Savanna will require establishment of endemic grass, forb, shrub, and tree species (Savanna) on sand soils on high elevation ridges > 500-year flood frequency, and with regular (5-8 year recurrence) disturbance from fire or herbivory to maintain a large grass component of these systems. In another example, restoring Intermediate BLH will require regeneration of specific-community tree species on clay or clay-loam soils in mainly Hpm1 geomorphic surfaces where a 2-5 year flood recurrence regime from backwater flooding from the Mississippi River can occur.



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Appendix A

Soil types associated with major vegetation communities in the SJNM.

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces ^a
Prairie	82017, 82018,	
	82020	Bosket Fine Sandy Loam in Pve
	82005	Malden Loamy Fine Sand in Pve
Savanna	82005	Malden Loamy Fine Sand except Pve
	82026	Broseley Loamy Fine Sand in Pve
Terrace Hardwood Forest	82000	Dubbs Sandy Loam in PvE, PvCl, Ps, PvI, PvI1, PvI2
	82015	Beulah Fine Sandy Loam
	82017, 82018,	
	82020	Bosket Fine Sandy Loam in PvCl, Ps, PvI1, PvI2
	82026	Broseley Loamy Fine Sand in PvCl, Ps, PvI1, PvI2
	82029	Canalou Loamy Sand
	82030	Clana Loamy Fine Sand
	82031, 82032	Scotco Loamy Sand
	82043	Farrenburg Fine Sandy Loam
	82050	Lilbourn Fine Sandy Loam
Slope Forest	82021	Crevasse Loam
	90020	Saffell Gravelly Loam
High BLH	82005	Malden Loamy Fine Sand in Hpm1, PvCl, Ps
	82027	Broseley Soils
	82031, 82032	Scotco Loamy Sand in PvI1, Hpm1
	82037	Dundee Silty Loam in PvE, Ps, PvCl, PvI1, PvI2, PvI
	82040	Dundee Silty Clay Loam
	82045	Forestdale Silty Clay Loam
	82057	Towosaghy Fine Sandy Loam

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces ^a
	86002	Falaya Silty Loam
	86005	Acadia Silty Loam
	86016	Commerce Silty Clay Loam in Pve, PvI
	86045	Reelfoot Silty Loam
	86061	Sikeston Loam
	86063	Sikeston Silty Clay Loam
	86067	Tiptonville Silty Loam
	86074, 86082, 90001, 90017, 90021, 90022	Alder Silty Loam Memphis Silty Loam
High BLH Natural Levee	82026	Crevasse Loam
	86093	Crevasse Loamy Sand
	86094	Crevasse Silty Loam
Intermediate BLH	82000	Dubbs Sandy Loam in Hpm1
	82037	Dundee Silty Loam in Hpm1
	82046	Forestdale Silty Clay Loam
	82058	Wardell Loam
	86015	Commerce Silty Loam
	86016	Commerce Silty Clay Loam in Hpm1
	86019	Cooter Silty Clay Loam
	86020	Cooter Silty Clay
	86027	Diehlstadt Silty Loam
	86028	Diehlstadt Silty Clay Loam
	86029	Gideon Clay Loam
	86030, 83031	Gideon Loam
	86039	Mhoon Silty Loam
	86046	Roellen Clay
	86048,86103	Roellen Silty Clay
	86071	Tunica Silty Clay Loam
	86075, 86084	Bowdre Silty Clay Loam
	86077	Cairo Clay
	86078	Cairo Silty Clay
	86090	Commerce Silty Clay Loam
	86096	Dundee Silty Clay Loam
	86107	Tunica Silty Clay Loam

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces ^a
Low BLH (including Bottomland)	82047 86009	Jackport Silty Clay Loam Alligator Silty Clay Loam
Lakes)	86011 86052 86054, 86055, 86107 86056, 86057, 86104 86060	Alligator Silty Clay Sharkey Clay Sharkey Silty Clay Loam Sharkey Silty Clay Sharkey-Steel Complex
Riverfront Forest	82017, 82018, 82020 82026 86012, 86080, 86088 86064, 86106 86066 86089	Bosket Fine Sandy Loam in Hpm1 Broseley Loamy Fine Sand in Hpm1 Caruthersville Very Fine Sand Steele Fine Sand Tiptonville Fine Sandy Loam Commerce Silty Loam

^a Soil type is present exclusively in a community unless the specific geomorphic surface(s) are listed: Pv – Early Wisconsin Pleistocene Valley Train Sikeston Ridge, Pvcl – Late Wisconsin Relict Valley Train Channels, Ps – Late Wisconsin Interfluve Sand Dunes, Pv1 – Late Wisconsin Braided Stream Terrace undifferentiated age, Pv11 – Late Wisconsin Braided Stream Terrace most recent deposition on Charleston Fan, Pv12 – Late Wisconsin Braided Stream Terrace older deposition, Hpm1 – Holocene Point Bar Mississippi River Meander Belt.

